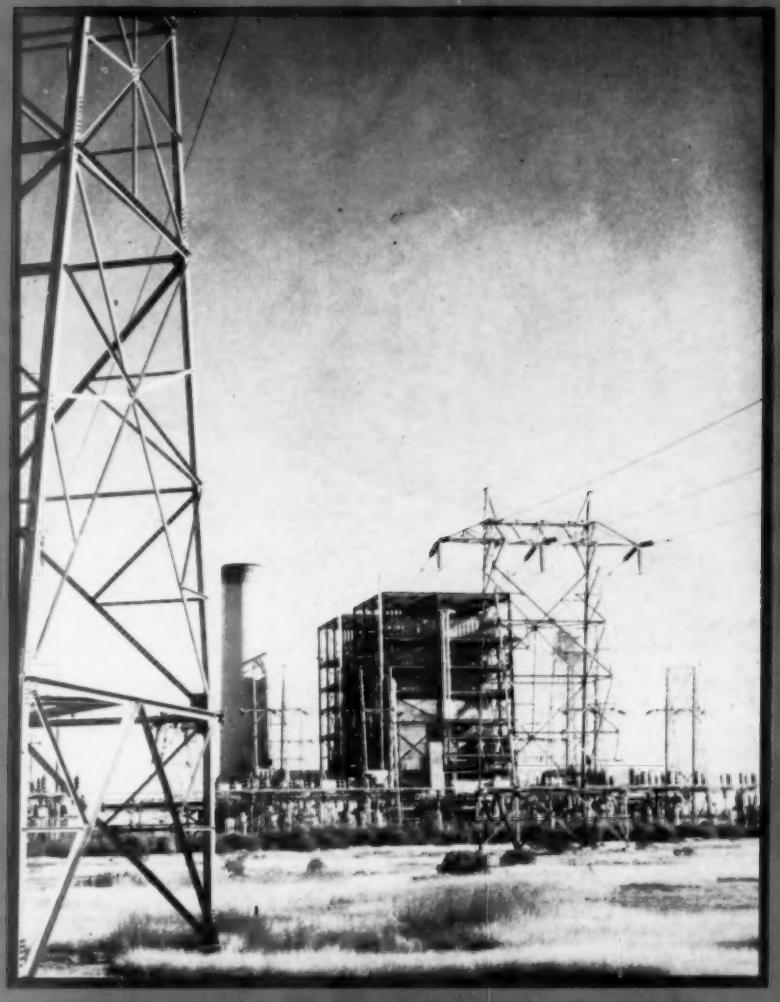
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

December 1959



Saguaro power plant of Arizona Public Service Co. near Tucson, Arizona

Pressure Jet Oil Burners

Boiler Tube Failures

ASME Annual Meeting Report—I

New Dutch Flagship completes maiden voyage

350 years after arrival of "Half Moon"

On September 11th, New York Harbor welcomed the Rotterdam, Holland-America Line's newest, largest and most modern liner.

The arrival of this 38,645-gross tonnage ship recalls the historic day 350 years ago when the Dutch vessel Half Moon first dropped anchor off Staten Island.

Ranking fifth in size among the world's passenger ships, the Rotterdam is fitted with all the improvements that modern engineering can provide for safety and comfort at sea.

Combustion Engineering had a very special interest in extending a hearty welcome to this notable ship, for the power that drives her is supplied by 4 boilers of C-E VERTICAL SUPERHEATER design, built by N. V. Koninkijke Maatschappij "De Schelde," Combustion's licensee in Holland. Each boiler has a normal rated capacity of 110,000 pounds of steam per hour. The Rotterdam is another notable ship added to the rapidly growing list of those powered by C-E Vertical Superheater Boilers.

Around the world Combustion Engineering continues to provide the most advanced designs of steam generating equipment for merchant and naval ships – including our Nuclear Navy.

COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.

C-242A

Canada: Combustion Engineering-Superheater Ltd.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

COMBUSTION

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Vol. 31 **No. 6**

December 1959

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COMBUSTION publishes its annual index in the June issue and is indexed regularly by Engineering Index, Inc. and also in the Applied Science & Technology Index.

The magazine is now reproduced and distributed to libraries on microfilm by University Microfilms of Ann Arbor, Michigan.

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Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING, INC.
Joseph V. Santry, Pres.; Charles McDonough, Vice-Pres.; Otto Strauss, Treas.; Thomas A. Ennis, Secy.
COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up; and to consulting engineers in this field. To others the subscription rate, including postage, is $4 in the United States, $5.50 in Canada, and $8 in Latin America and other countries. Single copies: Domestic, 40 cents, Foreign, 60 cents plus postage. Copyright 1959 by Combustion Publishing Company, Inc. Publication Office, Easton, Pa. Issued the middle of the month of publication.
Acceptance under Section 34.64, P.L. & R., authorized by United States Post Office.

BPA

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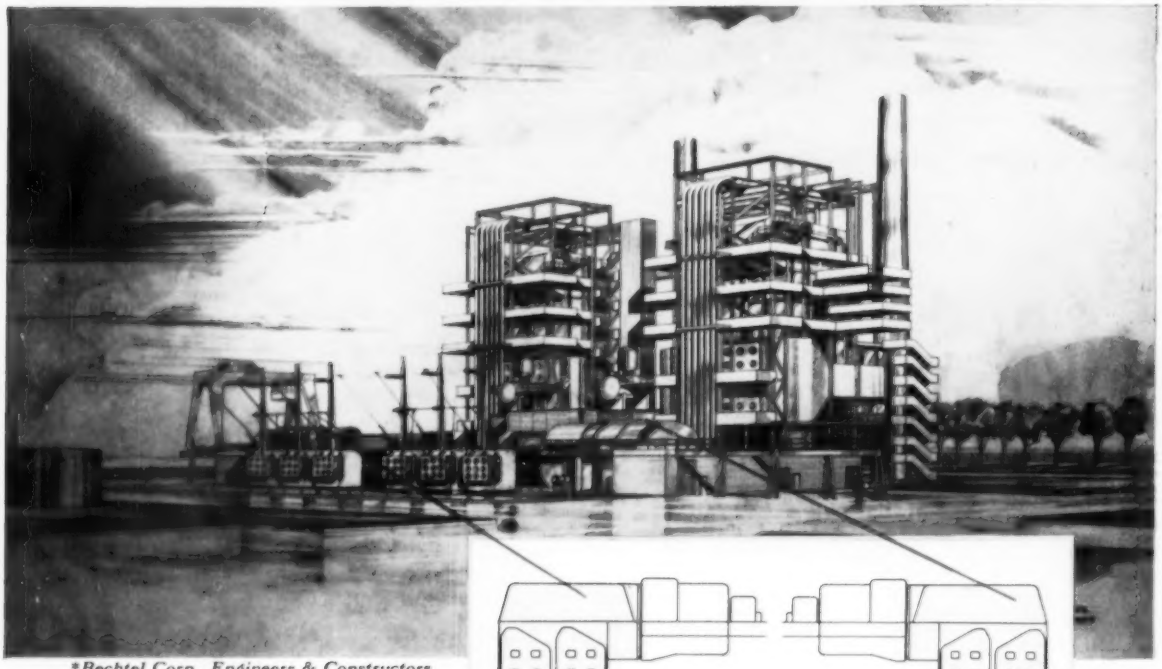
For Southern California Edison Company's new Huntington Beach Steam Station*...



*Bechtel Corp., Engineers & Constructors

Ingersoll-Rand

axial-inlet condensers

will serve each 200 MW unit

Designed for an eventual four units, the first two units of the new Huntington Beach Steam Station are now under construction. Turbines are cross-compound axial exhaust, 2400 psig., 1050°/1000°, 3600/1800 rpm. As indicated above in the artist's rendering, these units will be served by axial-inlet condensers, specially designed for this installation by Ingersoll-Rand. These I-R condensers are 2-pass units, each with 110,000 sq ft of surface.

In addition to the surface condensers, Ingersoll-Rand is furnishing the following associated equipment:

5 boiler-feed pumps rated 2020 gpm at 6400 ft TDH.

4 vertical condensate pumps, 3-stage, rated 2500 gpm at 350 ft TDH.

5 condensate booster pumps, rated 1851 gpm at 1970 ft TDH.

4 vertical condenser circulating pumps, rated 44,000 gpm at 35 ft TDH. The columns and discharge head sections are lined with Fiberglas.

2 steam-jet ejector units, 2-stage, single-element with surface-type inter and after condensers.

2 horizontal reciprocating vacuum pumps each driven by a 100 hp electric motor.

This installation is another dramatic example of Ingersoll-Rand's ability to meet the requirements of the modern steam plant... with advanced design surface condensers, pumps and associated equipment. Your I-R engineer will be glad to help you determine the equipment best suited to *your* requirements.

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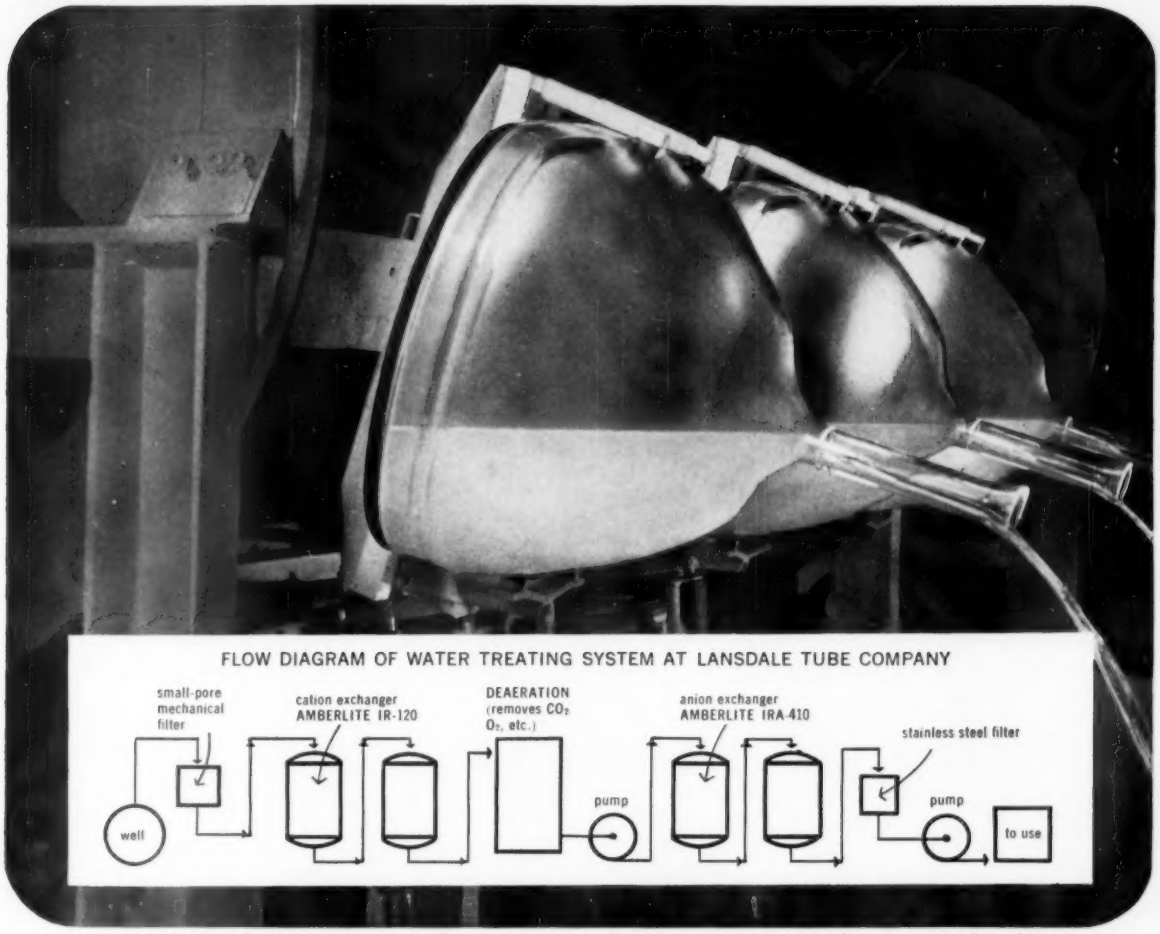
THERE'S NO SUBSTITUTE FOR EXPERIENCE IN ENGINEERED PRODUCTS

ION EXCHANGE RESINS pave the way for perfect TV pictures



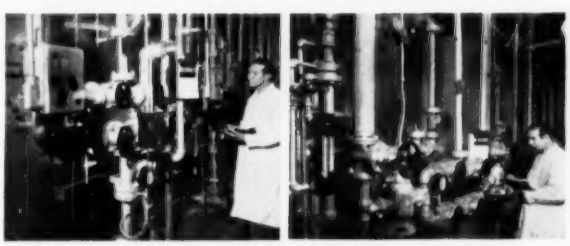
Water pouring from TV picture tubes carried fluorescent powder which has now settled on tube face. It must be free of ions in solution and carbon dioxide to prevent unwanted reactions and insure a smooth, blemish-free screen.

TV needs 100,000 gallons of AMBERLITE-treated water every day, at Philco's Lansdale Tube Co. Division

Plating perfect fluorescent screens on the inside of those big picture tubes calls for water completely free of metallic impurities and carbon dioxide—for washing tubes and preparing phosphor solutions. At Philco's Lansdale Tube Co. Division, the water treating system teams AMBERLITE IR-120 cation exchange resin and AMBERLITE IRA-410 anion exchange resin to provide water free of troublesome ions.

Water from the company's well contains 180 ppm hardness, 240 ppm dissolved solids, 150 ppm alkalinity. After treatment, deionized and filtered water shows over 600,000 ohm electrical resistance at 18°C., twice the required minimum for picture tube use. Water of 20,000,000 ohm resistivity at 18°C. for the manufacture of electronic components is obtained by passing the deionized water through small MONOBED units containing a mixture of AMBERLITE IR-120 and AMBERLITE IRA-400. AMBERLITE-treated water replaced distilled water in all manufacturing processes at Lansdale Tube Co. in 1947.

Can ion exchange help you? Your engineering company, qualified by experience in water conditioning, can tell you how AMBERLITE ion exchange resins may solve your problem. Write today for a copy of "If You Use Water . . . " 24 pages of the latest information on water conditioning.



Cation and anion exchange units in operation at Lansdale Tube Co.

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Perfect balance of skill and experience commends the Mitchell organization to your interest regarding your next job of critical piping. If you know the wisdom of delegating the prefabricating and erecting of high-pressure, high-temperature piping *directly* to specialists... by all means ask us in.

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Here are America's first six CE-Sulzer once-through boilers: All have L&N Direct-Energy Balance Control.

Company	*Station*	*Operating Pressure (psig)*	*Capability*
Dayton Power & Light Co.	Tait 4	2400	150 MW
Metropolitan Edison Co.	Portland 1	2400	165 MW
Dayton Power & Light Co.	Tait 5	2400	150 MW
Philadelphia Electric Co.	Eddystone 1	5000	325 MW
Cleveland Electric Illuminating Co.	Avon 8	3500	250 MW
Philadelphia Electric Co.	Eddystone 2	3500	325 MW

New L&N Direct-Energy Balance Control Coordinates Once-Through Boiler and Turbine

Philadelphia Electric Company's Eddystone Unit No. 1, the world's highest pressure and temperature (5000 psi and 1200°F) steam generator, employs the largest CE-Sulzer, once-through boiler ever built.

A new type of combustion control, Direct-Energy Balance, coordinates boiler-turbine operation by considering them as an integral unit. From combined steam pressure and generator intelligence, D.E.B. controls regulation of both fuel input and turbine governor valves. Excess air is "trimmed" automatically by flue gas oxygen analyzing equipment.

In the picture above, an operator at Eddystone is using the D.E.B. Control to set directly the desired rate of generation change. When he calls for a change in load, the control responds quickly, at the pre-set rate of change. Operation of the unit is integrated because (1) boiler-turbine output is changed in a predetermined, orderly manner, and (2) output is kept within the capabilities of the equipment in service.

In designing the Direct-Energy Balance method, L&N engineers sought a basic improvement over conventional combustion controls. Based on 30 years' experience in power plant measurements and controls, this new method was developed, subjected to simulation studies, and extensively field-tested. Direct-Energy Balance Control has also been selected for Unit 2 at Eddystone, a supercritical unit of 3500 psi. For information on this new concept in combustion control, call your nearby Field Office, or write for Reprint 463(8) to 4972 Stenton Avenue, Philadelphia 44, Pa.

Direct-Energy Balance Control... engineered to power plant standards by **LEEDS & NORTHRUP** Instruments — Automatic Controls • Furnaces

predictable, dependable performance...

Republic ELECTRUNITE Boiler Tubing offers Quality you can measure

Predictable, dependable Republic ELECTRUNITE® Boiler Tubes were used in the installation of a new power plant unit for the production of electricity for the Borough of Lansdale, Pennsylvania.

This new steam generator, engineered, manufactured, and erected by Riley Stoker Corporation, Worcester, Massachusetts, is designed to operate at 150,000 pounds of steam per hour, 1000 psi, at a steam temperature of 900° F.

Predictable . . . because ELECTRUNITE Boiler Tubing is hydrostatically or electronically tested to conform with the applicable ASTM specifications and the ASME Boiler and Pressure Code, as well as local, state, and boiler insurance requirements.

Dependable . . . because ELECTRUNITE Boiler Tubes are made from high-grade steel, produced in Republic's own mills. Operations, materials, and methods are carefully controlled from the time the ore is mined, through mill, and manufacturing processes.

Performance . . . proved on the job, job-after-job. Skilled craftsmen on the job report, "with ELECTRUNITE, the rolling goes well . . . the metal works properly, rolls in smoothly . . . we never worry about cracks in the tubing."

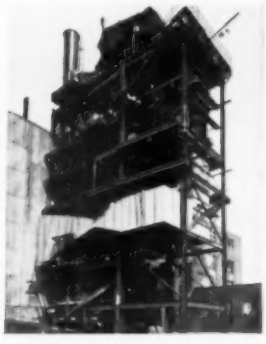
Get the facts. Learn more about Republic ELECTRUNITE for boiler, heat exchanger, condenser, evaporator applications. Call your Republic representative. Or, write direct.

FARROWTEST®—QUALITY YOU CAN MEASURE. Not a laboratory theory, not a mere inspection tool, but an exclusive production test that detects and rejects tubing containing defects of critical size. FARROWTEST is offered as an alternative to other less positive tests in accordance with table below, at no extra cost.

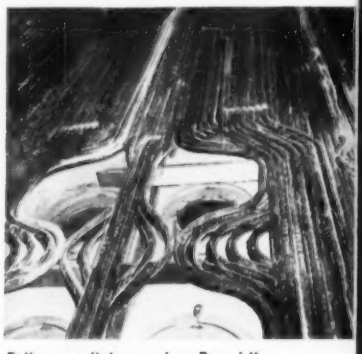
FARROWTEST REJECT TABLE

Wall Thickness (B.W. Gage)	Minor dimension of the defect (Length or Depth)	Defective Area (Length, Depth Plane)
20	.006"	.0025 sq. inches
18	.006"	.003 sq. inches
16	12½% of wall	.003 sq. inches
14 and 13	12½% of wall	.004 sq. inches
12 and heavier	12½% of wall	.005 sq. inches

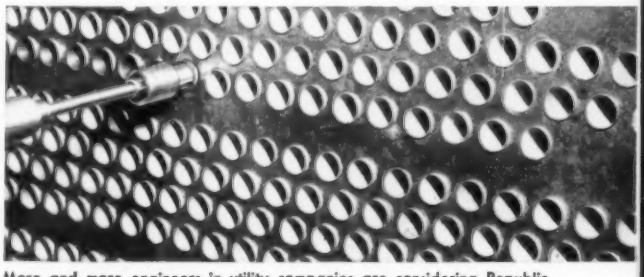
FARROWTEST detects and rejects not only tubing containing defects which completely penetrate the wall; but also tubing with defects equal to, or greater than, those shown in this table. For irregular defect shapes, a tube with defect area equal to or greater than shown above is rejectable. Where required, sensitivity of FARROWTEST equipment can be calibrated to reject defects of lesser specified area than shown in table, at extra cost.



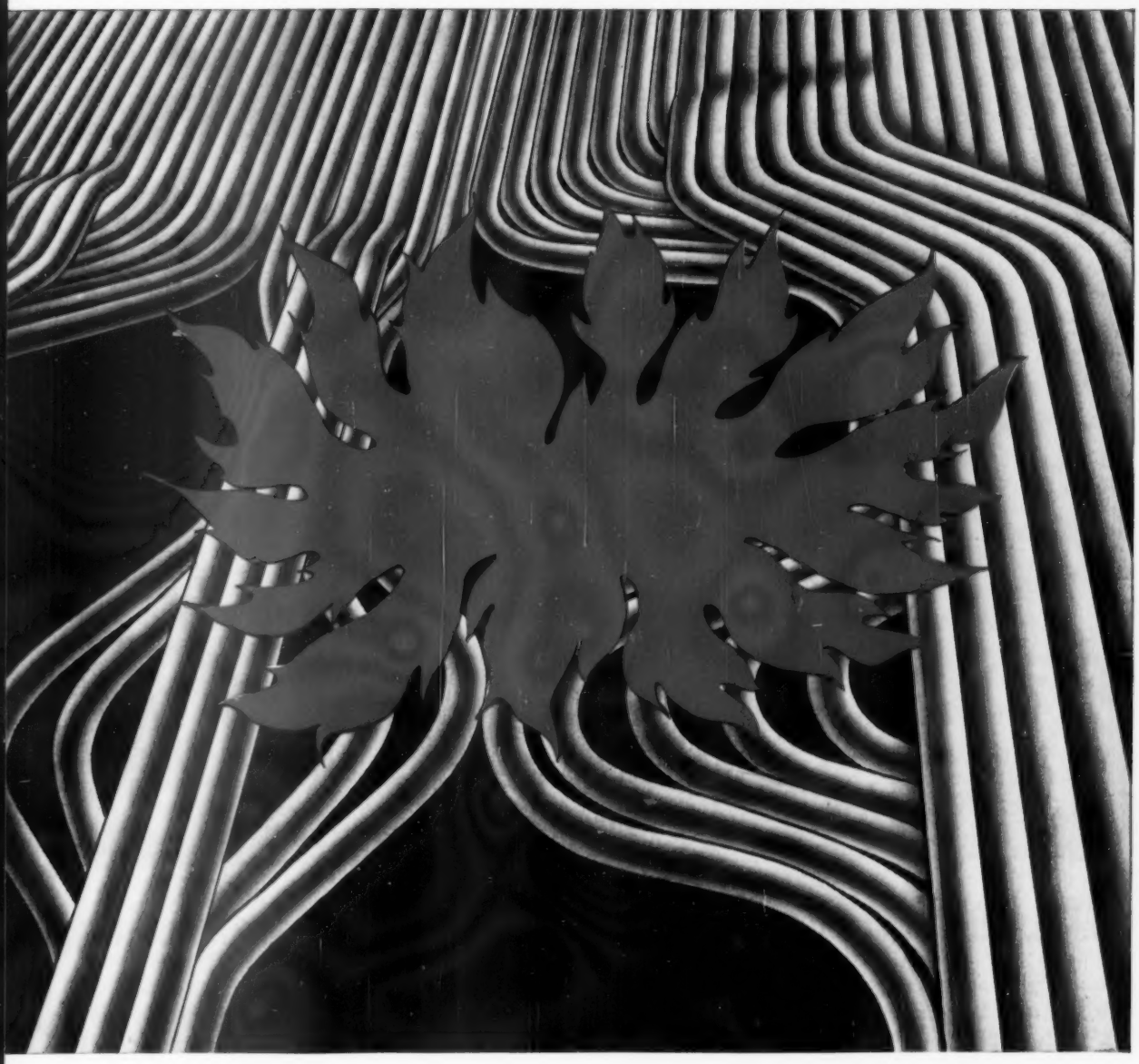
Power plant at Borough of Lansdale does not have a grate surface. Instead, powdered coal fuel which burns in suspension is fed in through water-cooled ports on front wall.



Full normalizing makes Republic ELECTRUNITE uniformly ductile for smooth, easy bending, trouble-free service. This view shows the fuel ports from the inside.



More and more engineers in utility companies are considering Republic ELECTRUNITE Stainless Steel Tubing for main surface condensers. Republic's ELECTRUNITE Stainless Steel resists corrosion, provides long, trouble-free service where water is used directly from natural sources. Call your local Republic ELECTRUNITE representative, or write for facts and data.



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STEEL AND TUBES DIVISION
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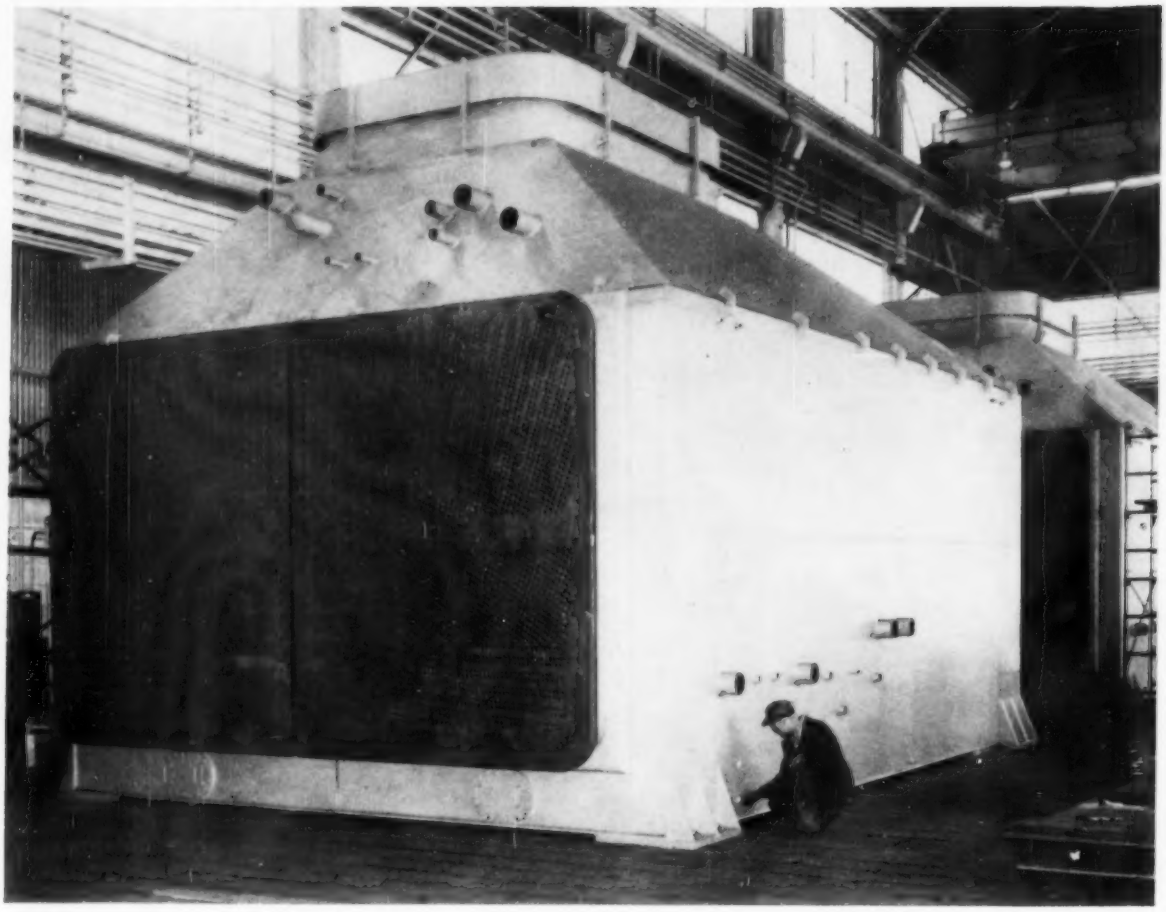
☐ ELECTRUNITE Heat Exchanger Tubing
☐ Carbon ☐ Stainless ☐ FARROWTEST Brochure

Name_____ Title_____
Firm_____
Address_____
City_____ Zone____ State_____



MARYLAND Steam Surface Condensers for installation in South America

Two 50,000-square foot condensers designed and manufactured by Maryland for installation in South America, have been stored at Maryland for over a year. Maryland is in an excellent position to provide storage service for customers desiring to order ahead of schedule, or faced with schedule changes. This service also enables our customers to take advantage of prevailing economic conditions.

As shown, units are ready for disassembly after shop erection and inspection. Both condensers are designed for outdoor service and incorporate seismic shock resistant features.

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Complete Engineering, specification and fabrication data on ***Maryland Surface Condensers.*** *It's yours without cost or obligation*

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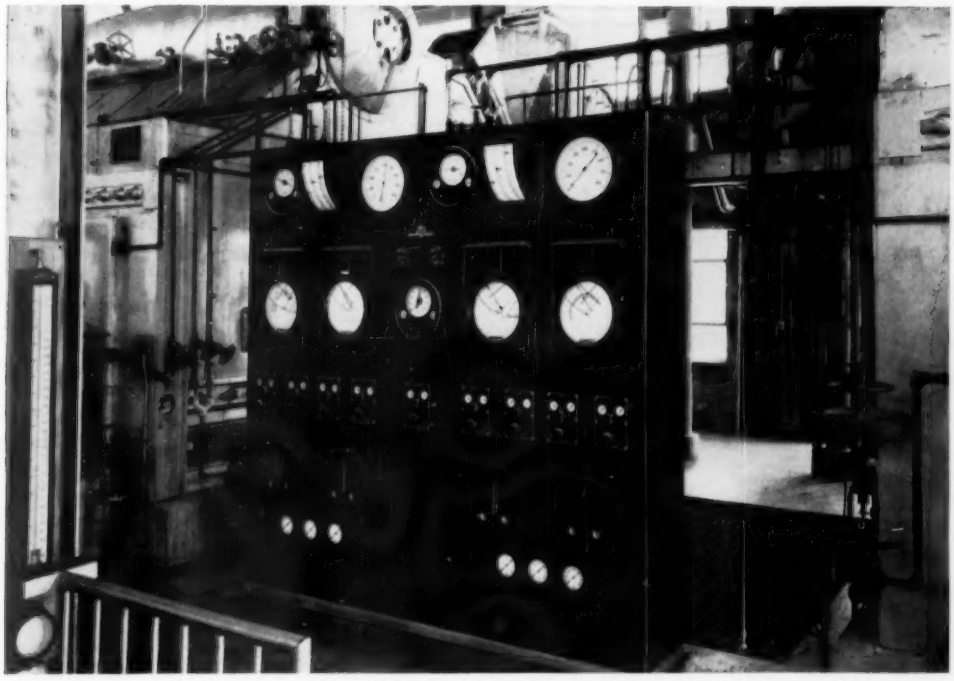

Bailey Meters and Controls for two boilers in a midwestern milling company.

How Bailey helps you get a new boiler off to a fast, safe start——

--The thrill of putting a new boiler "on-the-line" can be marred if you lack adequate metering and control equipment. You are a lot surer of a fast, safe start and dependable operation for a long time when you specify Bailey Meters and Controls. They are keys to peak efficiency and low operating costs.

Bailey is the choice of virtually all the most efficient plants on the Federal Power Commission's heat rate report. Here's why:

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You can be sure a Bailey Engineer will offer the right combination of equipment to fit your needs. Bailey manufactures a complete line of standard, compatible pneumatic and electric metering and control equipment that has proved itself. Thousands of successful installations involving problems in measurement, combustion, and automatic control are your assurance of the best possible system.

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Bailey Engineers have been making steam plants work more efficiently for more than forty years. Veteran engineer and young engineer alike, the men who represent Bailey, are storehouses of knowledge on measurement and control. They are up-to-the-minute on the latest developments that can be applied to your problem.

3. Sales and Service Convenient to You

There's a Bailey District Office or Resident Engineer close to you. Check your phone book for expert engineering counsel on your steam plant control problems.

31-1

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True measure of a high-heat coating's worth is *continuous operation at rated temperature*. Yet many so-called "heat-resistant" coatings take only occasional peaks — fail rapidly in 'round-the-clock service.

Dampney coatings are rated always for day in, day out operation at maximum temperatures. Hold them to it, if schedules call for steady heat, or let them fluctuate to ambient and back. Either way, Dampney silicones and ceramics give you full protection — with plenty in reserve.

Most important, Dampney coatings are selected to meet specific conditions of operation, temperature and corrosive environment. Thus they establish a lasting foundation easily maintained and permanently ending time-consuming and costly surface preparation.

Repeat orders — from a typical customer, 26 in 12 months for enough material to protect 1,929,000 square feet of steel — is the best evidence we have that when industry wants honest high-temperature coatings, it remembers Dampney silicones and ceramics, identified by the two trade names, DAMPNEY and THUR-MA-LOX.

We suggest you do likewise when you want real protection — resistant to 1000°F., to atmospheric corrosion, and to weather exposure — for these industrial hot spots . . .

stacks and breechings	•	turbine interiors
steam lines	•	precipitators
kilns	•	coke ovens
forced and induced draft fans	•	incinerators
heat-treating furnaces	•	pulverizers
autoclaves and retorts	•	blast and open hearth furnaces

Remember, too, the first Dampney trade name and product, known and used today the world around, APEXIOR NUMBER 1 for boiler interiors. For all hot metal, wet or dry, the best protection available is made and marketed by

MAINTENANCE FOR METAL

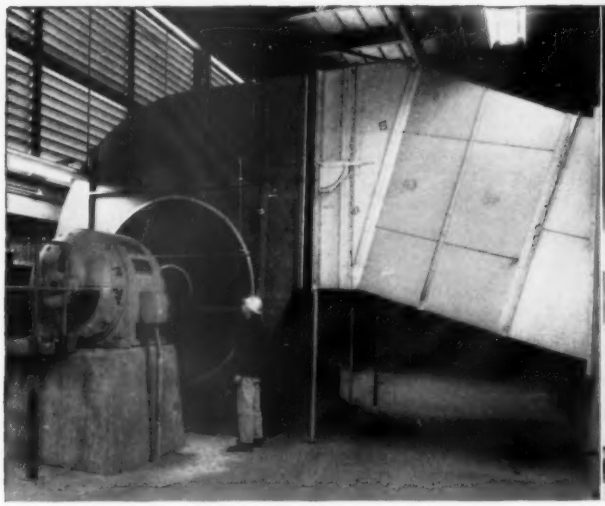
THE DAMPNEY COMPANY

HYDE PARK, BOSTON 36, MASSACHUSETTS

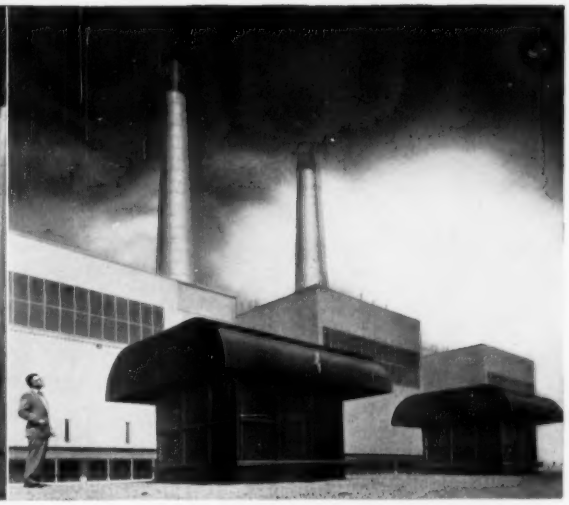
Coatings for all temperatures to high heat— all corrosive environments.

207

How do you plan to ventilate and heat your power plant?



WITH CENTRIFUGAL FANS?



WITH POWER ROOF VENTILATORS?

Both methods have their advantages. The type fan you select will naturally depend on the circumstances encountered in the layout of your station. To meet these requirements, "Buffalo" offers power roof ventilators, centrifugal fans and make-up air units well suited to the task. Above are two typical "Buffalo" boiler room and turbine room ventilation installations.

"Buffalo" Centrifugal Fans — These quiet, efficient, non-overloading fans have proved an excellent choice for boiler house ventilation. If desired, hot air may be ducted to other areas as needed. "Buffalo" Centrifugal Fans provide completely stable performance from free delivery to shutoff. Turbulence is reduced to a minimum by unique "Buffalo" design features. All wheels are factory-balanced to minimize vibration. Rugged construction throughout gives a long life of trouble-free service. Write for full details in Bulletins F-104 and F-201.

"Buffalo" Power Roof Ventilators — These dependable "packages" exhaust high volumes of hot air from large areas. They save money from the start, because little, if any, expensive duct work is required. Peak-efficiency "Buffalo" fans insure minimum operating costs. Installation does not interfere with valuable floor space. "Buffalo" Sky-Vent Power Roof Ventilators are complete units, quickly and easily installed. Capacities 1,000 to 250,000 CFM. Assembled packages include fan, motor, housing, roof curbing, stack and hood. Can also be arranged for supply with heating coils and dampers. Write for Bulletin FM-2345.

Your nearby "Buffalo" engineering representative will be glad to work with you on your boiler room ventilation problems. Phone him today, or write us direct.

"Buffalo"

BUFFALO FORGE COMPANY Buffalo, New York

Buffalo Pumps Division, Buffalo, N. Y.

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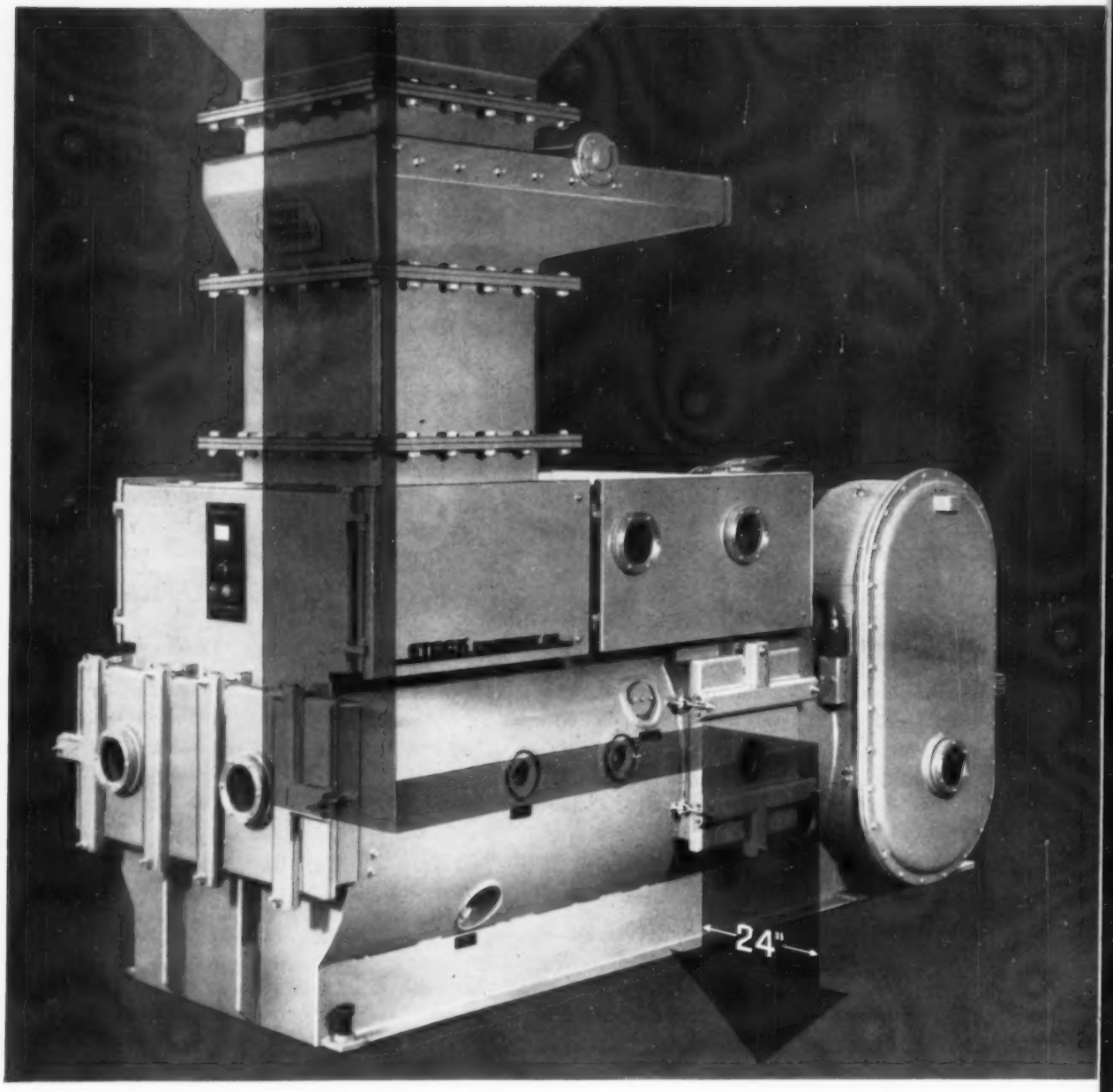
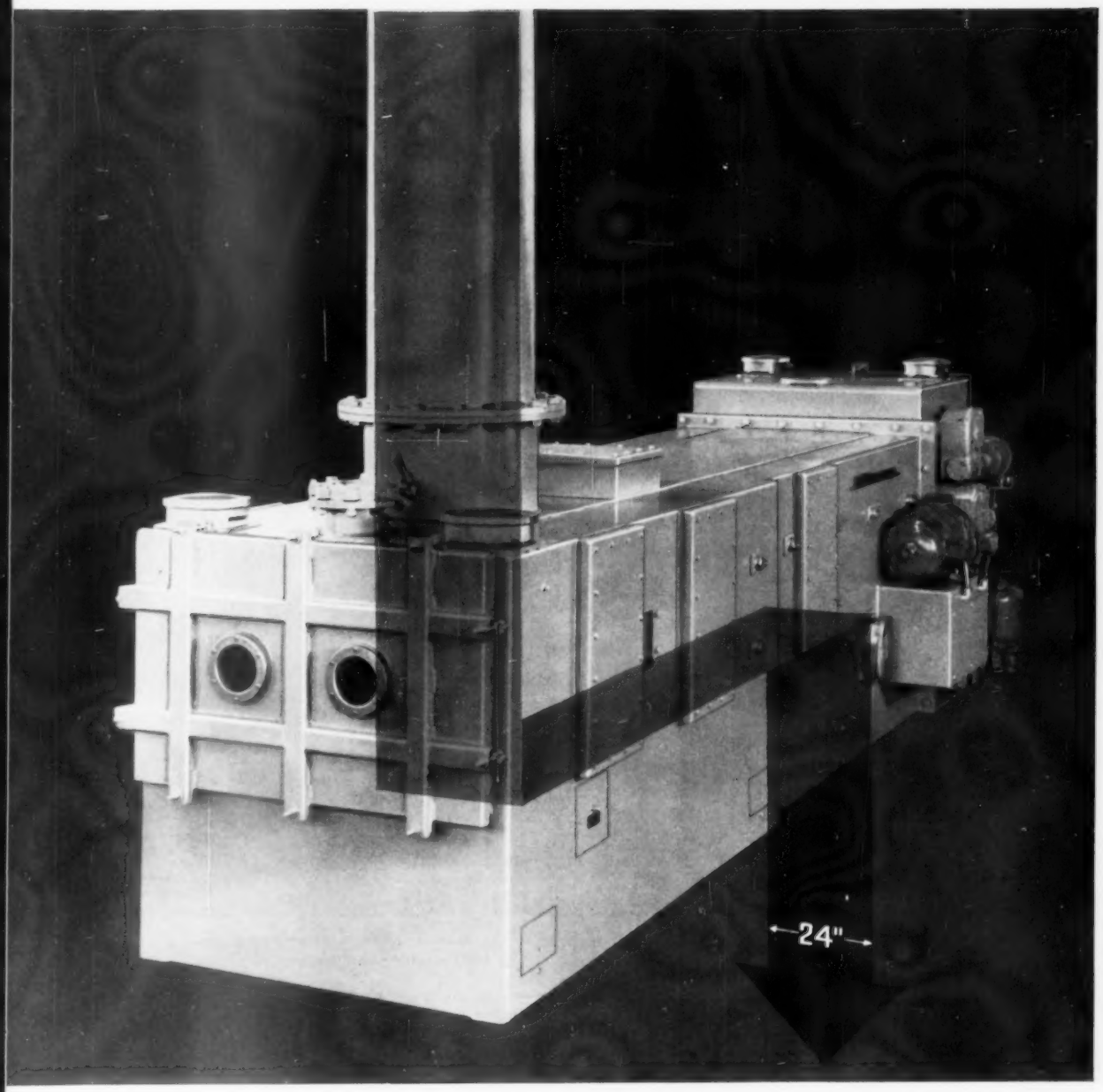


S-E-Co. Volumetric Feeders and S-E-Co. Gravimetric Feeders assure maximum reliability of coal feed to pulverizers and to cyclone burners because they carry the coal 24" wide on the feed belt. The 24" clear width provides ample space for the passage of oversize pieces of coal or occasional foreign objects. Not only does this contribute to reliability of feed, but it minimizes fluctuations in the volumetric efficiency and correspondingly leads to

24" WIDTH OF COAL ON BELT



a more uniform discharge. Carrying the coal in a 24" wide stream on the feed belt also means that wet, sticky coal is handled with the same ease as dry coal. It is the unobstructed 24 inches that provides the best assurance of uninterrupted feeder operation.

STOCK Equipment Company
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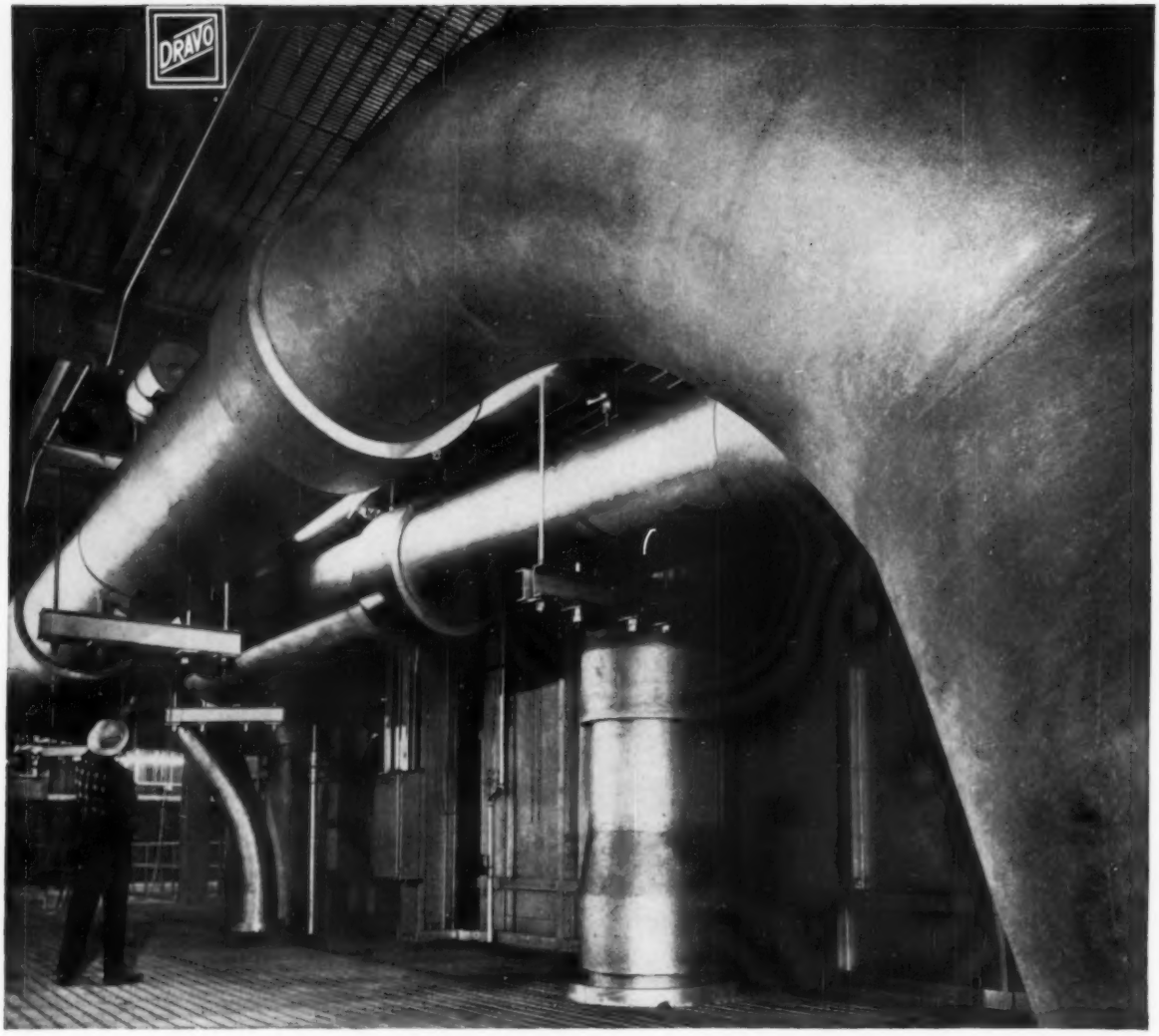
MEANS GREATEST RELIABILITY



Three-inch wall main steam piping. Boiler will operate at 2400 pounds per square inch and 1050° Fahrenheit.

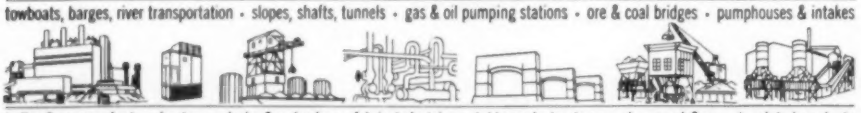
Race track for 227,000 horses

At Ohio Edison's new Stratton power station, high pressure, high temperature steam races through this heavy wall piping at 125 miles per hour, creating more than 227,000 horsepower in the turbine.

In addition to main steam and boiler feed lines the project included instrument piping and all auxiliary systems. This is the first of four 170,000 kw units to be installed at the Stratton station; Dravo will fabricate piping for all four.

Inquiries are invited on this or any of the engineered products and services listed below. Write DRAVO CORPORATION, PITTSBURGH 25, PENNSYLVANIA.

towboats, barges, river transportation · slopes, shafts, tunnels · gas & oil pumping stations · ore & coal bridges · pumphouses & intakes



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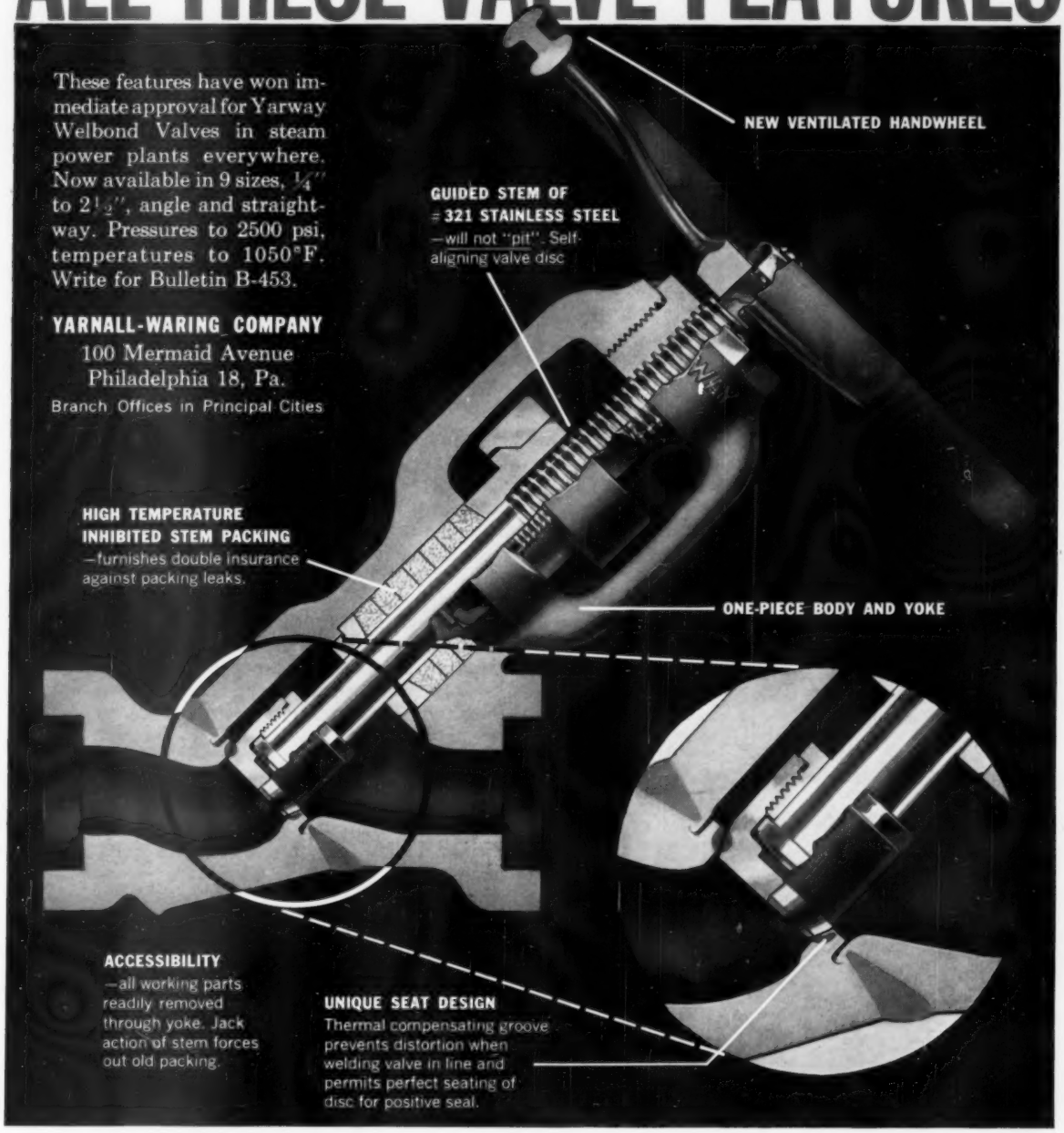
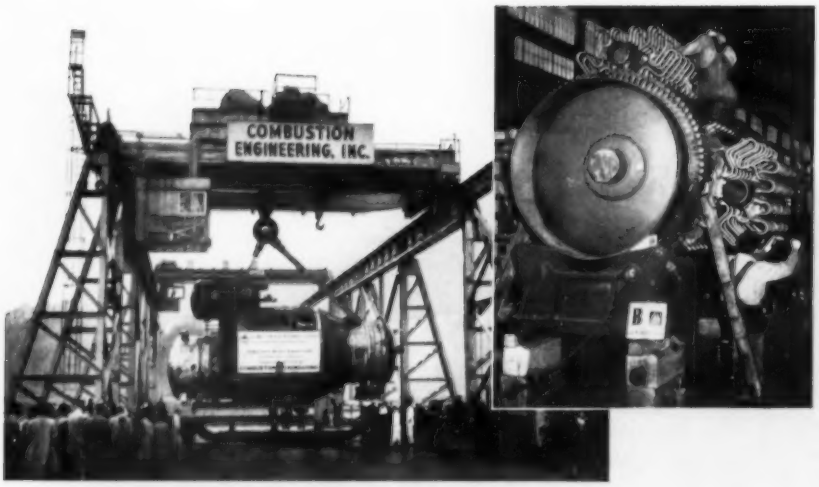
ONLY WELBOND® COMBINES ALL THESE VALVE FEATURES


These features have won immediate approval for Yarway Welbond Valves in steam power plants everywhere. Now available in 9 sizes, ¼" to 2½", angle and straightway. Pressures to 2500 psi, temperatures to 1050°F. Write for Bulletin B-453.
YARNALL-WARING COMPANY
100 Mermaid Avenue
Philadelphia 18, Pa.
Branch Offices in Principal Cities
NEW VENTILATED HANDWHEEL
GUIDED STEM OF #321 STAINLESS STEEL
—will not "pit". Self-aligning valve disc
HIGH TEMPERATURE INHIBITED STEM PACKING
—furnishes double insurance against packing leaks.
ONE-PIECE BODY AND YOKE
ACCESSIBILITY
—all working parts readily removed through yoke. Jack action of stem forces out old packing.
UNIQUE SEAT DESIGN
Thermal compensating groove prevents distortion when welding valve in line and permits perfect seating of disc for positive seal.

YARWAY WELBOND ... is the valve for high pressures/high temperatures

REPRESENTATIVE USERS OF YARWAY WELBOND VALVE: Houston Lighting & Power Co. Jersey Central Power & Light Co. Boston Edison Co. Virginia Electric & Power Co. Connecticut Light & Power Co. City of Independence, Mo. Aluminum Co. of America City of Pasadena, Calif. Mississippi Power & Light Co. Rochester Gas & Electric Corp. Ohio Edison Co. Central Hudson Gas & Electric Corp.

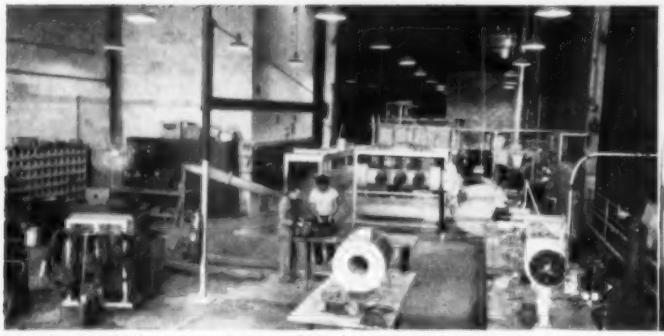


(Left) The huge riverside crane at Combustion's Chattanooga Division easily lifts this 92-ton stainless steel reactor vessel — the most complex reactor vessel built to date — into a barge for shipment to the Enrico Fermi Power Station, Lagoona Beach, Michigan.
(Right) Stainless steel sodium heat exchanger consisting of a series of tubes within tubes, encased in a pressure vessel.

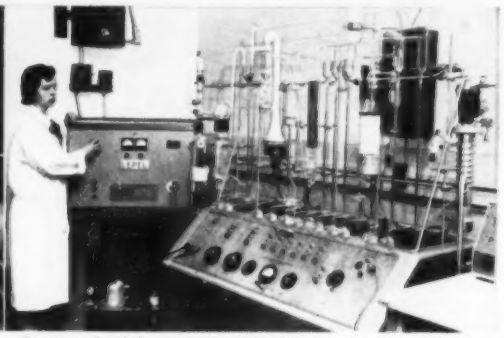
What C-E is doing to advance

The strange and wondrous world of the atom has been examined and surveyed by C-E scientists and engineers since 1946. The object–to put the controlled energy of the atom to productive use for the generation of power. The result –a wealth of knowledge and experience in the application, design and manufacture of nuclear power equipment. Backed by specially designed laboratories and manufacturing facilities, this knowledge and experience–greatly augmented and enriched by the acquisition of the General Nuclear Engineering Corporation early this year–has enabled C-E to undertake many kinds of nuclear work.

Notable C-E and General Nuclear projects are outlined on the opposite page. Virtually all of them are *current*, and many have a significant relationship to the vital task of making nuclear power competitive with conventional power. Collectively, these projects will contribute importantly to the Company's objective of achieving the same position of leadership in the atomic world of tomorrow which it has long since achieved in present-day methods of power generation.



Partial view of laboratory of General Nuclear Engineering Corporation at Dunedin, Florida, showing equipment used for the study of a high-pressure, high-temperature gas coolant system.



Portion of a laboratory at C-E's Nuclear Division, Windsor, Connecticut, showing gas analysis equipment used for detecting the presence of small quantities of gases in reactor materials.

The 520-foot-long Heavy Vessel Bay at C-E's Chattanooga Division was created especially for the manufacture of heavy nuclear components.

Portion of the 530-acre site occupied by C-E's Nuclear Division at Windsor, Connecticut. This Division is equipped for the development, design and test of reactor systems and the manufacture of reactor cores and core components.

Nuclear Power Progress

C-E NUCLEAR PROJECTS

For Electric Power Stations

- In association with Stone & Webster Engineering Corporation, a design study for AEC of an advanced type of large (236,000 kw) pressurized water reactor power plant.
- A long-term development program for AEC to determine the best means of using nuclear energy to generate superheated steam. (Success in this endeavor will be a big step forward in reducing the cost of nuclear-generated power.)
- Design studies for the Puerto Rico Water Resources Authority, under AEC contract, to determine the best means of adding nuclear superheat to a boiling water reactor.
- Design, research and development work covering a gas-cooled, heavy-water-moderated, pressure-tube type reactor for the East Central Nuclear Group, Inc., and the Florida West Coast Nuclear Group. This development will also lead to a nuclear power plant using superheated steam.
- The development and test of various kinds of fuel elements and fabricating procedures, under contract with the AEC.
- The design and manufacture of reactor vessels, including the largest and most complex vessels of their type built to date, for the Shippingport Station (America's first full-scale atomic power plant), the Enrico Fermi Atomic Power Plant, the Humboldt Bay Nuclear Power Station, and Italy's first nuclear power plant.

For Military Power Plants

- Design study for U. S. Army, under AEC contract, of a truly package type of nuclear reactor, using the boiling water concept, for remote installations. This program includes operation of a prototype boiling water reactor at the National Reactor Testing Station in Arco, Idaho, and the training of military technicians in the operation of the installation.
- The conceptual design and operation of a nuclear test reactor, under AEC contract, to permit full-scale testing of prototype reactor cores for military field plants.

For Naval Power Plants

- The design and manufacture of a submarine reactor system designed to set new standards of accessibility, speed of startup and operational flexibility—and the operation of a land-based prototype installation.
- The design and manufacture of numerous reactor cores, reactor vessels, steam generators and pressurizers for various types of submarines and naval surface ships.

For Merchant Ship Propulsion

- The design and engineering study of a prototype pressurized water reactor for a 45,000-ton tanker, under contract with the AEC and the U. S. Maritime Commission.

Special Studies and Services

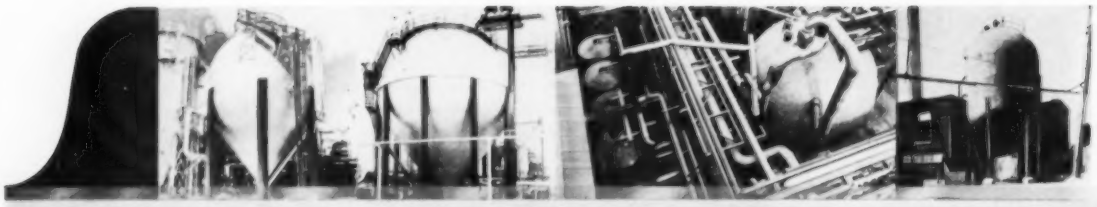
- Irradiation studies, fabrication studies, evaluation studies of the general properties of materials, quality control, isotopic analyses, strain gauge and photoelastic testing, basic and applied research in ferrous metallurgy.
- Bio-assays, decontamination, environmental monitoring, radiochemical analyses and radiological safety programs.

COMBUSTION ENGINEERING

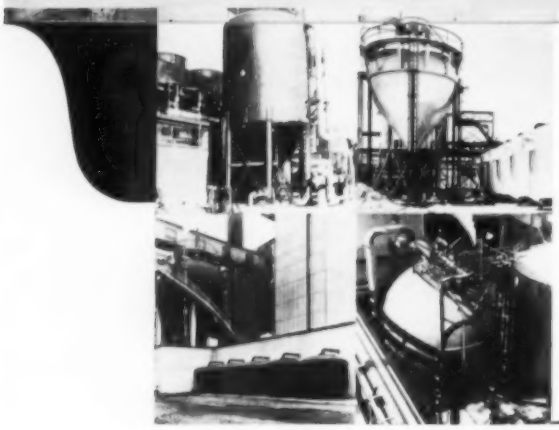
Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.

C-248

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE



Designed to Handle—



Variable Flow

High Silica

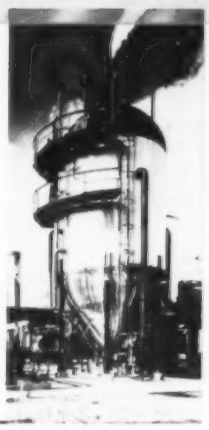
High Turbidity

Hardness Removal

Alkalinity Reduction

Varying Chemical Composition

Oxygen Removal



GRAVER HOT PROCESS-HOT ZEOLITE SYSTEMS

No matter what the service condition—variable flow rates, changing raw water composition, high turbidity, high silica, or any combination of the above, Graver Hot Process-Hot Zeolite Systems are designed to consistently produce the required quality effluent. This means *lowest* turbidity, silica, alkalinity and hardness.

Your conditions may require the use of sludge blanket, external sludge recirculation, integral deaeration, handling of condensate, complete automation, or any combination of these. Graver has actual experience in the design, fabrication and operation of the exact unit you need to do the job. This experience has been gained from hundreds of installations during the past 50 years and from our extensive research and development program.

Designed to meet the needs of today's processing industries requiring makeup treatment to medium pressure boilers, Graver Hot Process-Hot Zeolite Systems assure uninterrupted operation with the best possible treatment results under all feed conditions.

WRITE FOR DESCRIPTIVE LITERATURE

GRAVER

Industrial Water Treatment Dept. I-330

GRAVER WATER CONDITIONING CO.

Division of Union Tank Car Company

216 WEST 14TH STREET, NEW YORK 11, N.Y.

THE WESTERN PRECIPITATION

"Transistomatic" CONTROL

BY FAR, the Industry's Most Advanced Precipitator Control...

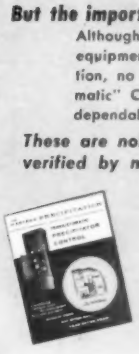
NO TUBES! NO RELAYS! NO COUNTERS!

and carries a Lifetime Guarantee!

In the electrostatic precipitation of dust, fume and fly ash, no installation is completely modern without *automatic* control to maintain optimum Precipitator efficiency as the characteristics of the gas stream fluctuate. Compared with manual control, automatic control is not only more sensitive and more efficient, but actually costs less because of the vital savings it makes in labor and operating costs . . . *savings so important that no profit-minded operator will want to be without them.*

But the important point to remember is this—
Although many manufacturers of precipitation equipment offer units for precipitator automation, no other unit is equal to the "Transistomatic" Control for foolproof simplicity, rugged dependability or control accuracy!

These are not idle claims. They can be easily verified by making your own comparison . . .



A DESCRIPTIVE BOOKLET
that gives further information will gladly be sent on request. Write, wire or phone our nearest office!

Compare ACCURACY! The "Transistomatic" does not base its "sensing" action on spark *frequency* alone—or spark *intensity* alone. Instead, it continuously integrates BOTH frequency and intensity to establish an overall "power value" that provides a new standard of control accuracy!

Compare DEPENDABILITY! The "Transistomatic" unit contains no parts of any kind requiring regular replacement. Moreover, the entire unit is completely sealed—moisture-proof and watertight.

Compare GUARANTEES! The "Transistomatic" is so foolproof and trouble-free it carries a *lifetime guarantee!*

BEFORE YOU BUY ANY automatic precipitator control, be sure to get the complete "Transistomatic" story. A folder is available giving additional data. Or see your nearest Western Precipitation representative for further details!

WESTERN PRECIPITATION CORPORATION

Engineers and Constructors of Equipment for Collection of Suspended Material from Gases . . and Equipment for the Process Industries

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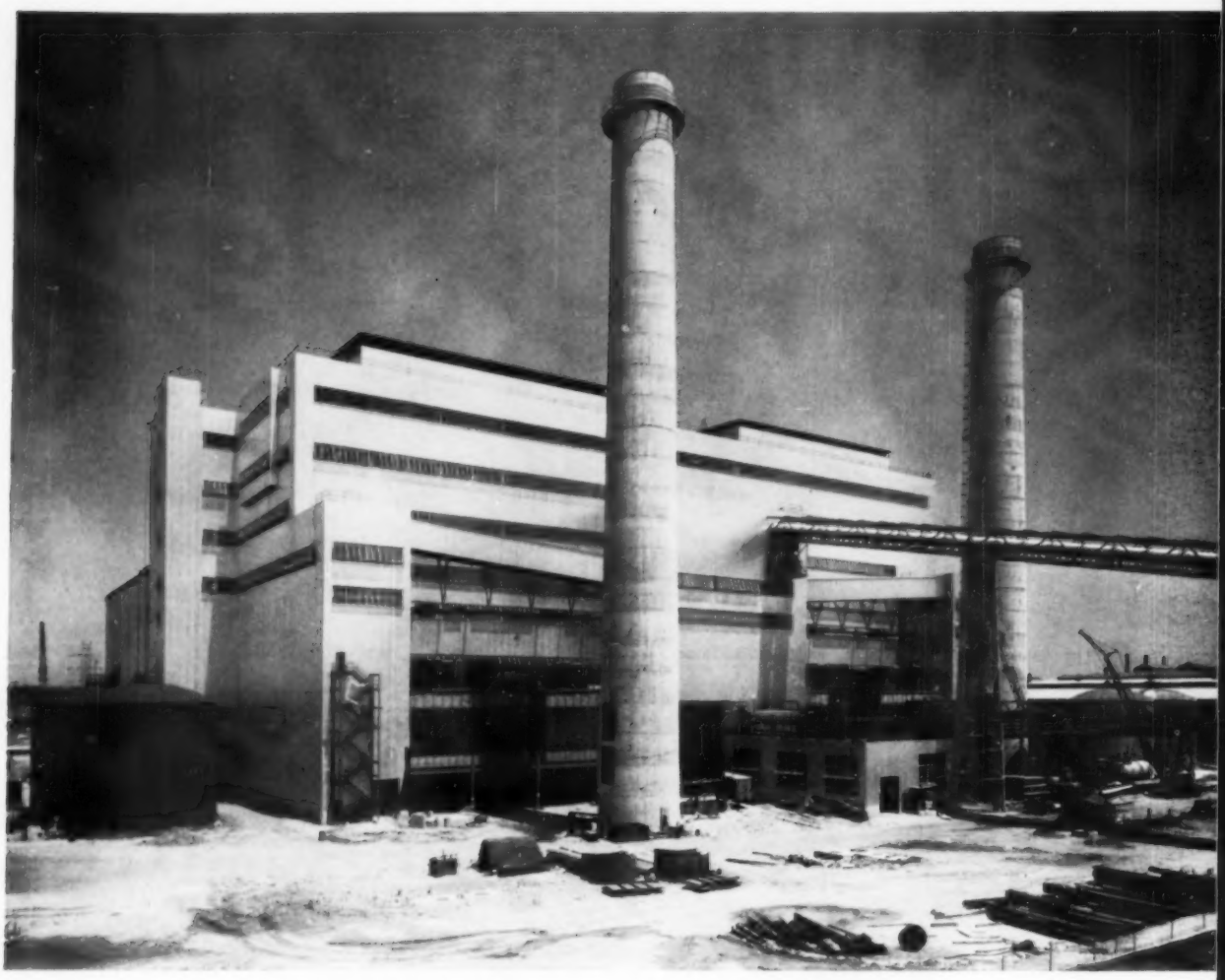
Representatives in all principal cities

Precipitation Company of Canada Ltd., Dominion Square Bldg., Montreal



Eddystone Station's Unit 1 has a capacity of 2,000,000 lb/hr at 5000 psig. and 1200°/1050°/1050°/F . . . uses C-E Sulzer Monotube Steam Generator.

Vulcan Selective-Sequence system provides Eddystone Station with precision soot blowing

When Unit 1 of Philadelphia Electric's Eddystone Station goes into operation, a Vulcan Selective-Sequence system will accurately control all soot blowing.

Selective-Sequence systems were chosen for both units 1 and 2 at this super-critical station because they assure positive, dependable boiler cleaning . . . make the most efficient use of the blowing medium.

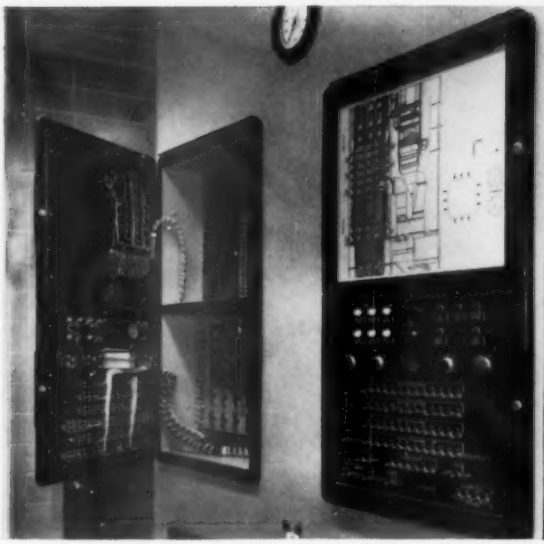
Vulcan Controller saves time. Without leaving the panel, the operator pushes a master button to place the system in sequential operation. He can see that each soot blower is operating in sequence for the proper interval with adequate pressure. He can modify the sequence to improve cleaning or conserve the blowing medium without time-consuming wiring and piping changes.

Vulcan long retractables speed cleaning. With dual-motor drive, Eddystone's T-30's clean uniformly; minimize the danger of tube cutting or erosion. Low rotating speed increases range and penetration of cleaning, decreases wear, eliminates whip, and permits proper cleaning with faster traversing speeds.

Half-'tracts with 19-foot travel, wall deslaggers, and air pre-heater controls are also used.

COPES-VULCAN DIVISION
BLAW-KNOX COMPANY, ERIE 4, PA.

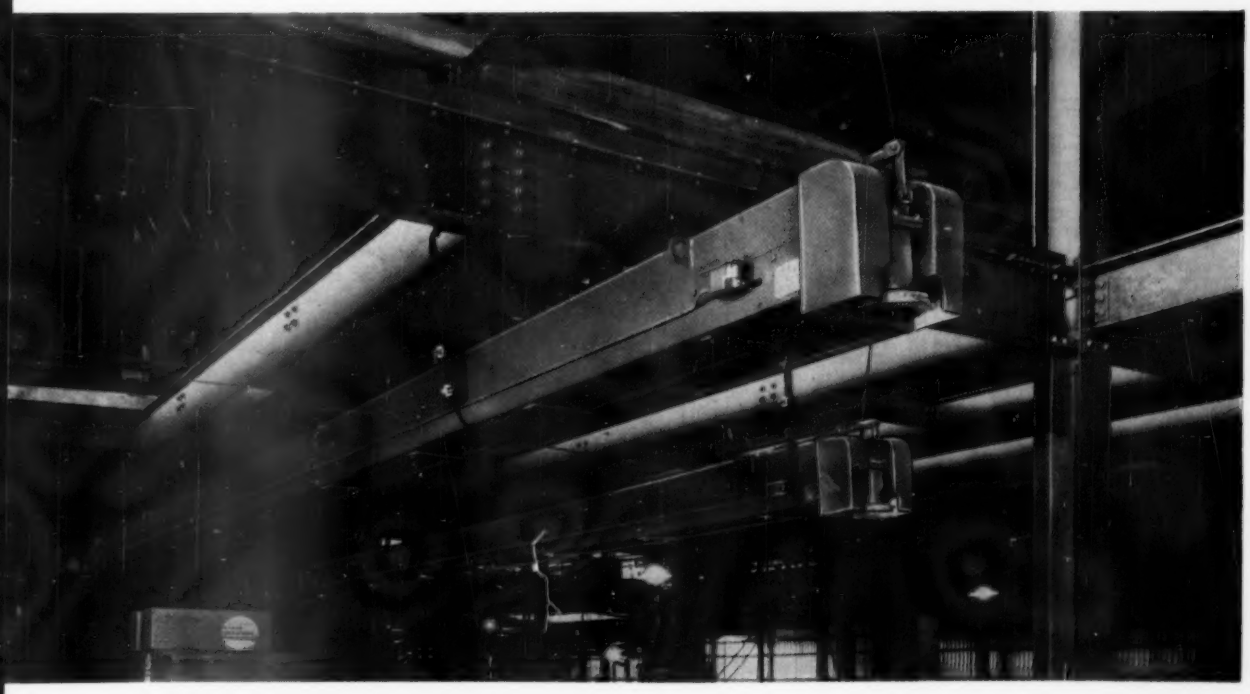
BLAW-KNOX

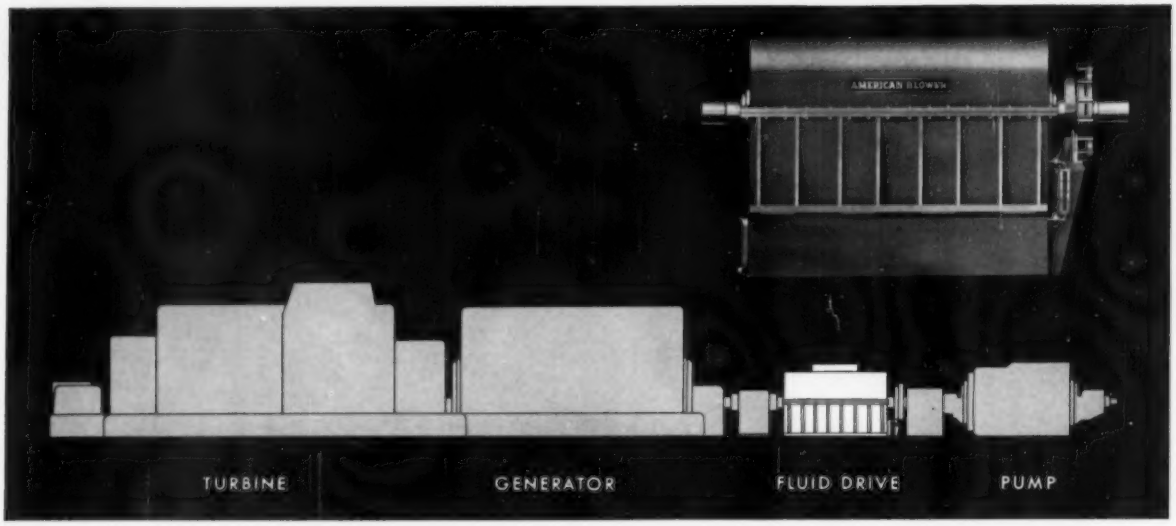


Panel provides centralized control of soot blowing at Eddystone. With the Vulcan SSC-120 Selective-Sequence controller, each blower can be operated four times during a schedule, or there can be four different schedules. The sequence can be varied by means of a jack board. Any soot blower can be operated at any point in the sequence by plugging one end of a patch cord into the blower jack, and the other end into the desired sequence jack. Write for Bulletin 1029.

Wall deslagger conserves steam generated at Eddystone by three special package boilers. High striking power of Vulcan RW-3E drives off gummy masses to assure high heat-transfer capacity, and uniform superheat and reheat temperature control. Dual motors are used: one speeds the nozzle to and from the blowing position, the other rotates it slowly for thorough cleaning. All parts are covered for protection, assuring long life with low maintenance. Write for Bulletin 1034.

Vulcan T-30's have 30- and 37-foot travels. Motors are mounted at the boiler end to facilitate maintenance, yet away from heat of the boiler wall. Their placement avoids interferences. Write for Bulletin 1030.

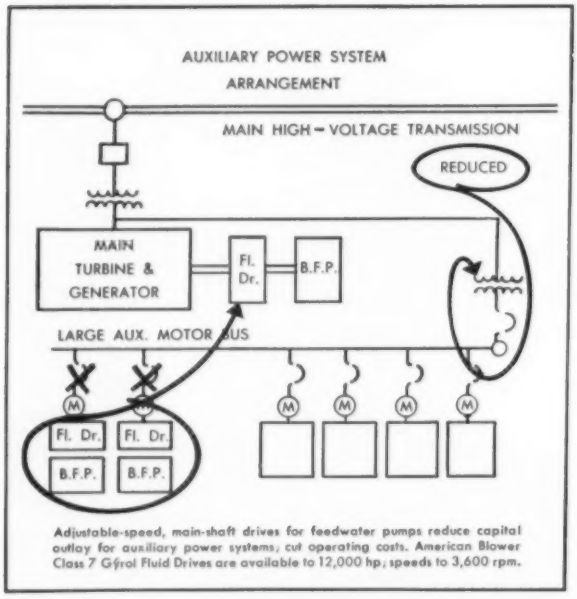




Gýrol® Fluid Drive lets you:

Take boiler feed-pump power from main-turbine shaft . . . slash auxiliary costs!

Save price of motors, switchgear, conduit and cable. Release more power to consumer lines. Reduce operating costs.



Adjustable-speed, main-shaft drives for feedwater pumps reduce capital outlay for auxiliary power systems; cut operating costs. American Blower Class 7 Gýrol Fluid Drives are available to 12,000 hp; speeds to 3,600 rpm.

Savings of nearly $500,000 are predicted for two 290-Mw turbine generator units scheduled for service this year, one of which has been operating since April '59. Both use main-turbine feedwater pumps driven through American Blower adjustable-speed Gýrol Fluid Drives.

Savings are fourfold:

1. **Shaft-end pumps eliminate costly electrical accessories necessary for motor-driven feed pumps.**
2. **Auxiliary demands are reduced, so more power can be released to consumer lines.**
3. **Gýrol Fluid Drive saves power over the entire operating range. It offers adjustable-speed pump control that eliminates wasteful throttling; reduces wear by operating pumps at speeds to fit boiler demands.**
4. **Fluid Drives may effect reduced piping and high pressure heater costs since these auxiliaries may be designed for maximum operating rather than pump shut-off conditions.**

Let an Industrial Division product specialist show you how Gýrol Fluid Drive can save power, cut costs . . . improve operating efficiency. Contact our nearest office, or write: American-Standard* Industrial Division, Detroit 32, Michigan. In Canada: American-Standard Products (Canada) Ltd., Toronto, Ontario.

* American-Standard and Standard are trademarks of American Radiator & Standard Sanitary Corporation.

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INDUSTRIAL DIVISION

AMERICAN BLOWER PRODUCTS • ROSS PRODUCTS • KEWANEE PRODUCTS

Warmest Wishes for a Merry Christmas

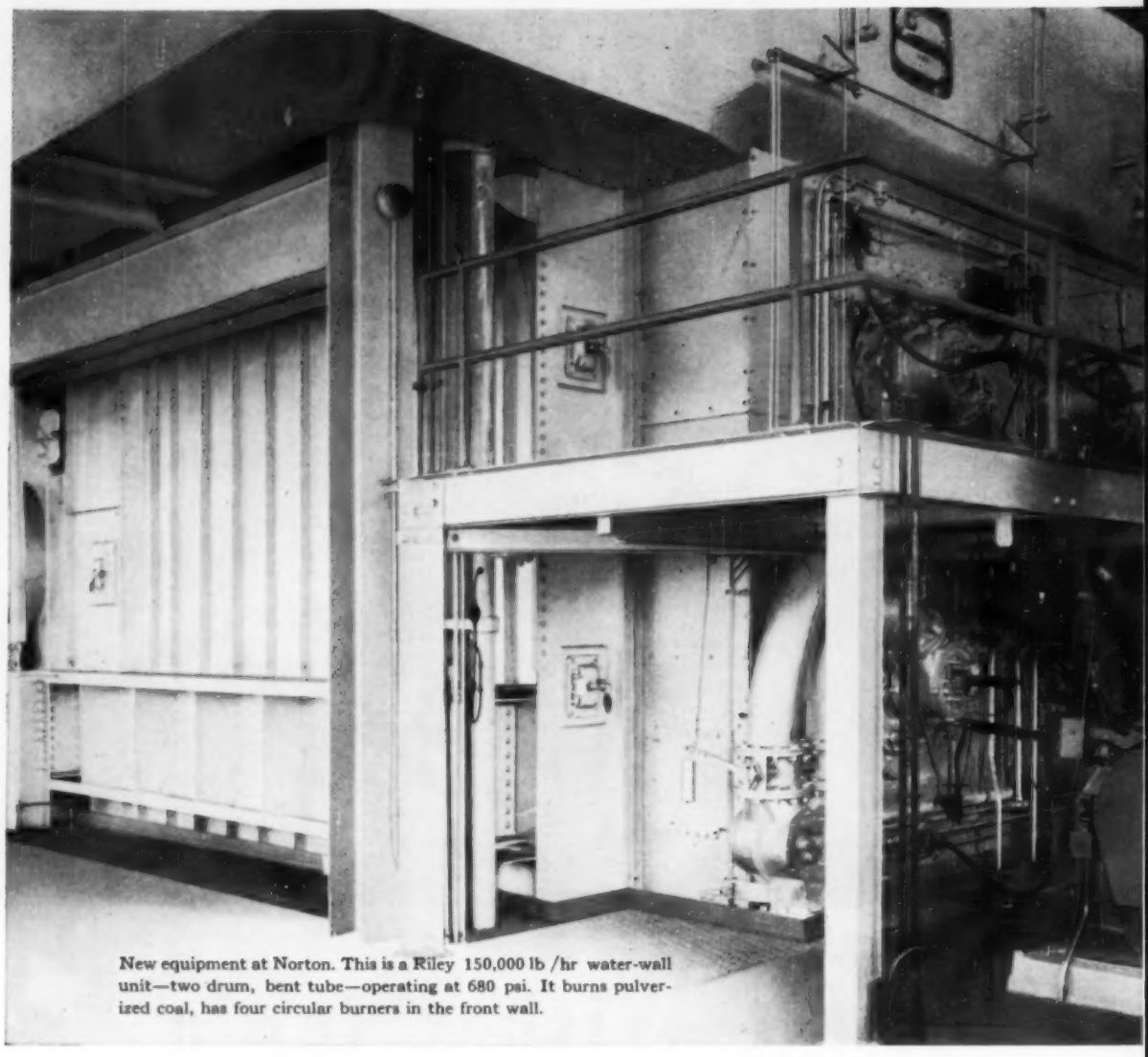
EASTERN GAS AND FUEL ASSOCIATES

BEACON COAL

EASTERN GAS AND FUEL ASSOCIATES

PITTSBURGH BOSTON CLEVELAND DETROIT NEW YORK NORFOLK PHILADELPHIA SYRACUSE

For New England: New England Coal & Coke Co. *For Export:* Castner, Curran & Bullitt, Inc.



New equipment at Norton. This is a Riley 150,000 lb /hr water-wall unit—two drum, bent tube—operating at 680 psi. It burns pulverized coal, has four circular burners in the front wall.

Coal proves best dollar

NORTON COMPANY FINDS COAL STILL IS LOWEST COST

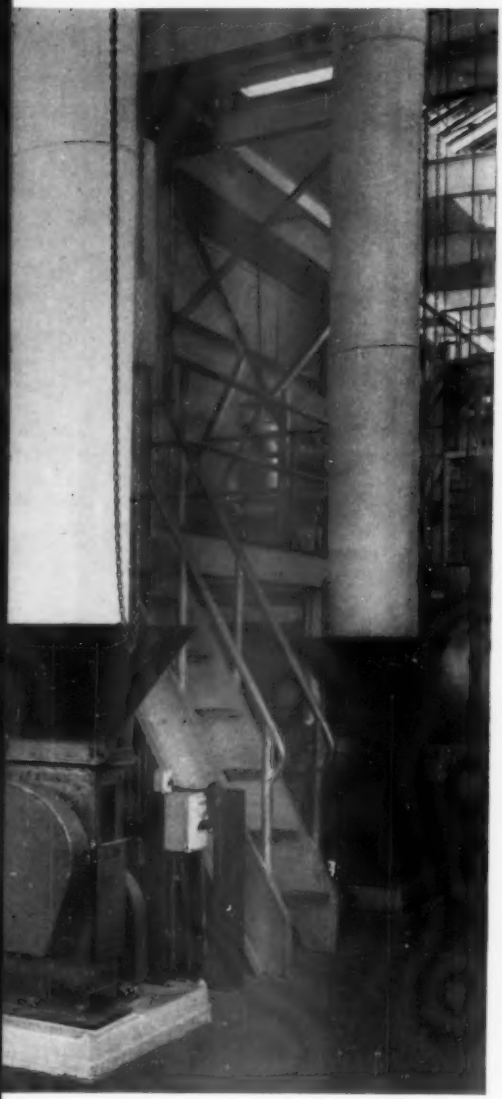
As plant facilities expanded, the Norton Company, Worcester, Mass., world's largest manufacturer of abrasive products, required greater quantities of steam for heating, hot water, electricity and process work. This expansion prompted an engineering survey to determine future power needs. As a result, Norton staff engineers—working with K. R. Warrington, Consulting Engineers—decided to install additional steam generating equipment. Coal had been used previously because it was the most economical of the fuels in that area when the original plant was installed. Coal *continues* as the fuel of the new plant for the same reason. Norton management is sold on the fact that, dollar for dollar, coal is the best fuel buy.

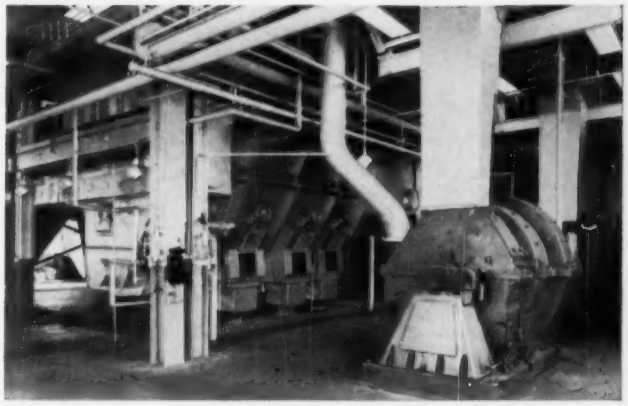
COAL IS LOWEST COST FUEL

Today, *when the annual cost of fuel often equals the original cost of the boilers*, you should know that bituminous coal is the lowest cost fuel in most industrial areas. And modern coal-burning equipment gives you 15% to 50% more steam per dollar, while automatic operation trims labor costs and eliminates smoke problems. What's more, tremendous coal reserves and mechanized mining procedures assure you a constantly plentiful supply of coal at stable prices.

CONSULT AN ENGINEERING FIRM

If you are remodeling or building new heating or power facilities, it will pay you to consult a qualified engineering firm. Such concerns—familiar with the latest in fuel





In the center, ash hoppers—part of United Conveyor steam vacuum ash handling system—lead to underground conveyor which moves ashes to outside storage silo. At right: coal pulverizers.

From track hopper, 100 ton/hr boom conveyor (right) carries coal to storage area. Bucket conveyor (center) lifts it to belt conveyor at top of plant. Coal handling system by William T. Donovan Co. and Jeffrey Manufacturing Co.

buy

FUEL IN ITS AREA

costs and equipment—can effect great savings for you with the efficiency and economy of coal.

TECHNICAL ADVISORY SERVICE

To help you with fuel problems, the Bituminous Coal Institute offers a free technical advisory service. We welcome the opportunity to work with you, your consulting engineers and architects. If you are concerned with steam costs, write to address below or send coupon. Ask also for case histories booklet, complete with data sheets. You'll find them informative.

BITUMINOUS COAL INSTITUTE

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See our listing in Sweet's Files: A-30i/Bi; PE-4a/Bi; IC-18b/Bi

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Guide Specifications, with complete equipment criteria and boiler room plans:

Bituminous Coal Institute, Dept. C-12
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Gentlemen: Please send me:

☐ GS-1 (low-pressure heating plant, screw-type underfeed stoker).

☐ GS-2 (high-pressure heating and/or process plant, ram-type underfeed stoker).

☐ GS-3 (automatic package boiler for heating and process plants).

☐ Case histories on larger plants.

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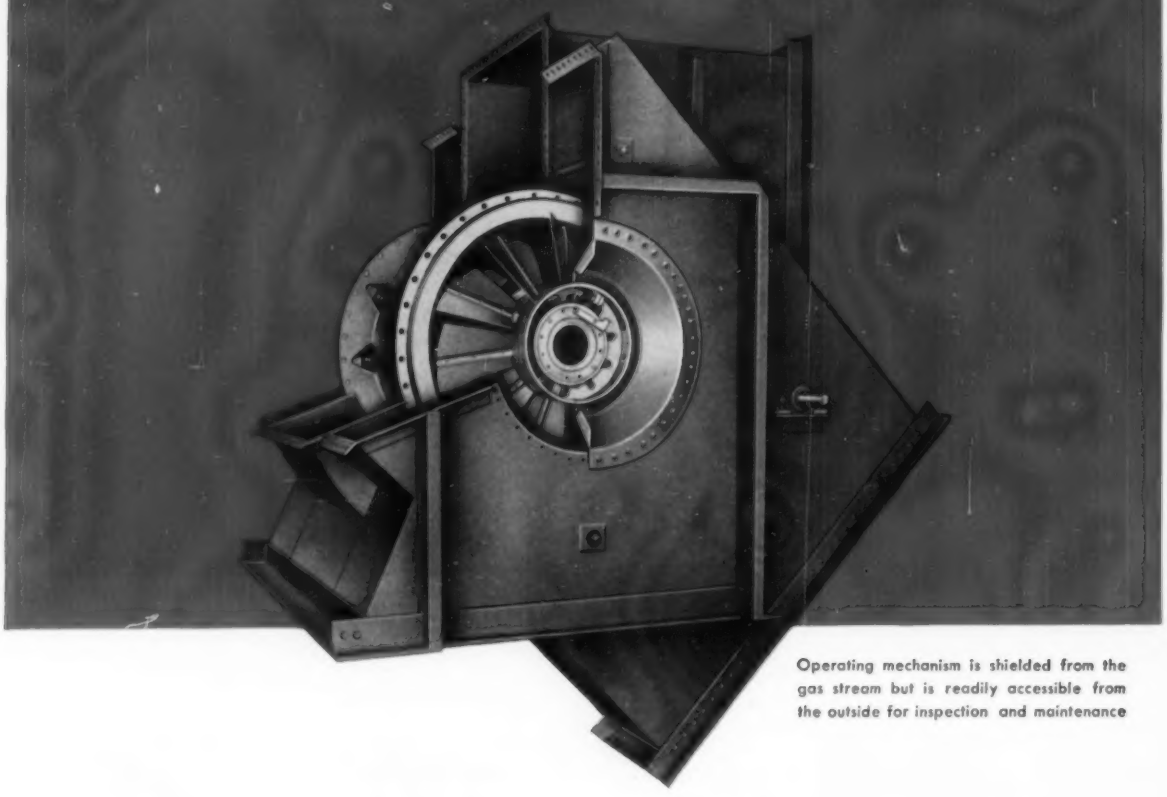
Title _____

Company _____

Address _____

City _____ Zone _____ State _____

Westinghouse Volume Control helps pay off fly ash dust control investments



Operating mechanism is shielded from the gas stream but is readily accessible from the outside for inspection and maintenance

Westinghouse inlet vane air spin control is a *proven* low cost method of regulating Induced Draft fan output when using dust arrestors.

Many major power producers are using Westinghouse Inlet VANE CONTROL® on coal-fired induced draft fan applications, paying off their investment in dust control. Ask your Sturtevant Division Sales Engineer for a list of their names and installations — or, write Westinghouse Electric Corporation, Hyde Park, Boston 36, Mass.

PLANTS AT HYDE PARK, MASS., LA SALLE, ILL., BERKELEY, CALIF.

YOU CAN BE SURE... IF IT'S Westinghouse

Watch "Westinghouse Lucille Ball-Desi Arnaz Shows" CBS-TV Fridays

J80697

KELLOGG ENGINEERS

BUILD LONG LIFE

INTO POWER PLANTS

With costs of downtime constantly climbing, the soundest investments in new central stations today are those engineered for optimum protection against failure tomorrow.

This is one of the reasons why The M. W. Kellogg Company, worldwide engineers and builders of plants for basic industries, is so frequently charged with the execution of large capital expenditures by electric utilities—one industry vital to all.

In central stations functioning 24 hours every day, a major Kellogg responsibility is to install and weld the hundreds of feet of heavy-walled main steam lines that keep steam flowing to the turbines, as well as much of the auxiliary piping.

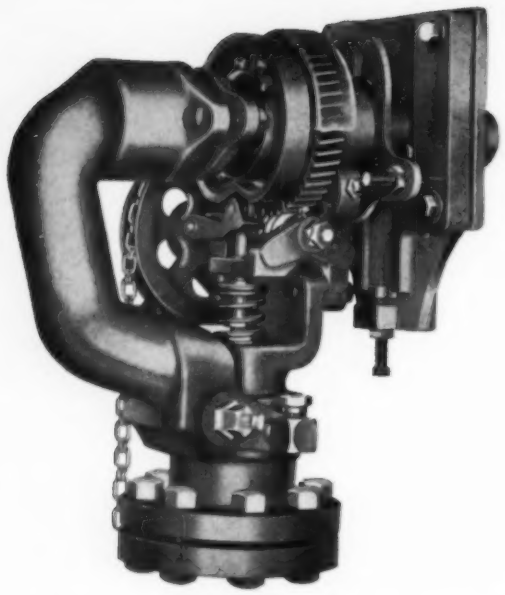
Through Kellogg's metallurgical background and the company's development of special field-welding techniques, the security of Kellogg K-Welds® on stainless, chrome-moly, and high quality carbon steel piping is assured for the life of the steam generating system.

Kellogg's role in the erection of one major utility's newest power station is fully described in the 12-page booklet—"The Eddystone Story." Inquiries for this booklet are invited from consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.

THE M. W. KELLOGG COMPANY

711 Third Avenue, New York 17, N.Y. *A Subsidiary of Pullman Incorporated*

Offices of Kellogg subsidiary companies: Toronto, London, Paris, Buenos Aires, Caracas, Rio de Janeiro



Quick Opening Bayer Soot Blower Valves Assure

- 100% cleaning efficiency
- minimum steam consumption
- superior high temperature resistance

The Bayer Balanced Valved Soot Blower is a single-chain operated design that assures precise sequential operation of the valve and element. *Only* after the start of full steam flow does element rotation commence—a feature which provides positive and efficient cleaning over the entire arc. . .without wasting steam.

The Bayer Soot Blower is simply operated by a pull on the chain which opens the cam-actuated valve. Continued pulling of the chain slowly rotates the element through its cleaning arc, at the end of which the valve automatically closes.

For severe high temperature locations, "super service" elements of Bayer-developed "Chronilloy" are available. Of superior strength, wrap-resistance, and stability, these elements resist the oxidation and chemical action caused by very high temperature gases.

In over fifty years of continuous specialized service, the Bayer company has equipped more than 35,000 boilers with dependable soot blowers. Engineered for long life and low maintenance, Bayer products assure economical and trouble-free operation.

ADVANTAGES OF THE BAYER BALANCED VALVED SOOT BLOWER

- single chain operation
- individual elements adjustable for high pressure service by orifice plate valve
- full steam pressure over entire cleaning arc
- selected gear ratios for optimum rate of element rotation
- minimum pressure drop through valve body
- machined air seal with spring loaded seat
- complete vacuum breaker protection
- precision swivel tube alignment lessens stuffing box packing needs
- load carried on ring type thrust bearings

For further information contact the Bayer representative nearest you. He is an experienced engineer, qualified to service Bayer Soot Blowers.

Agencies

New York	Cleveland	Boston	Los Angeles	Charlotte	Salt Lake City	Washington, D. C.
Philadelphia	Detroit	Seattle	Cincinnati	Richmond	Houston	Atlanta
Chicago	Pittsburgh	St. Paul	Indianapolis	Denver	Kansas City	Tulsa

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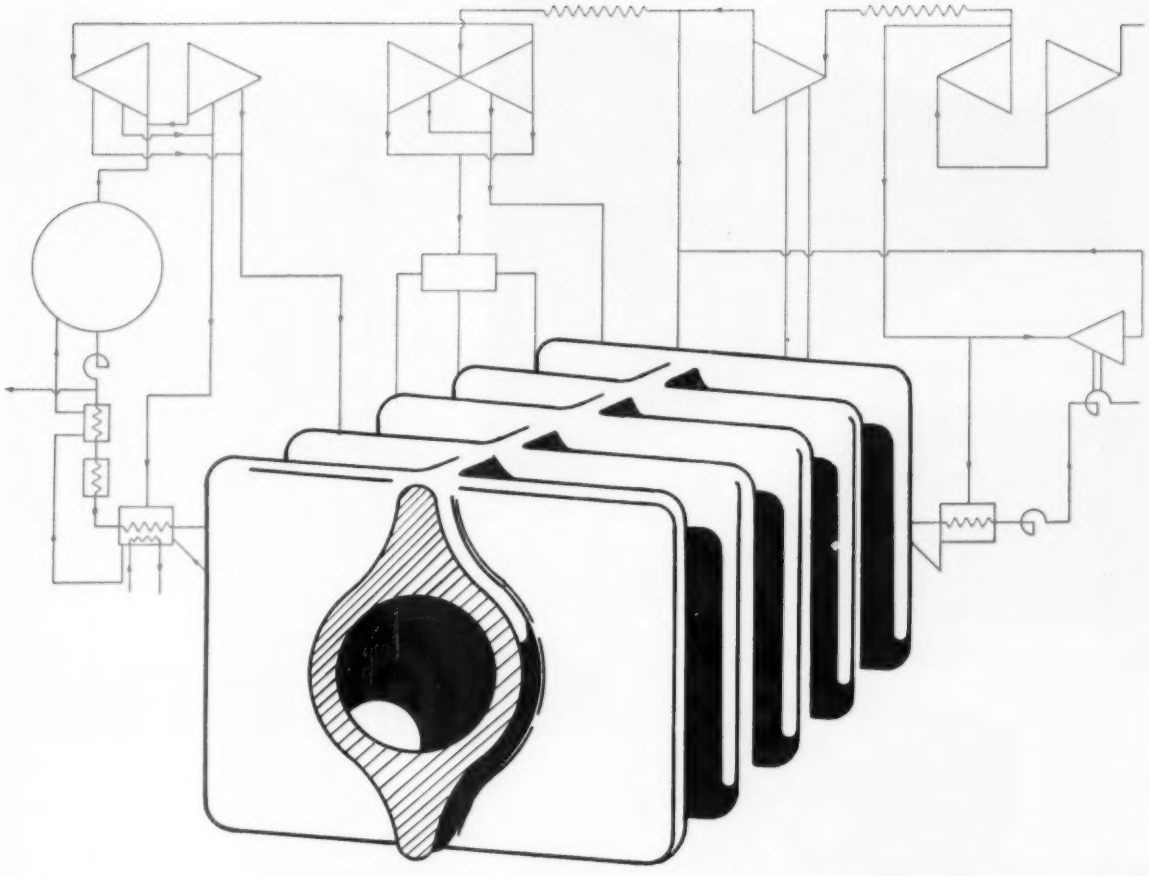

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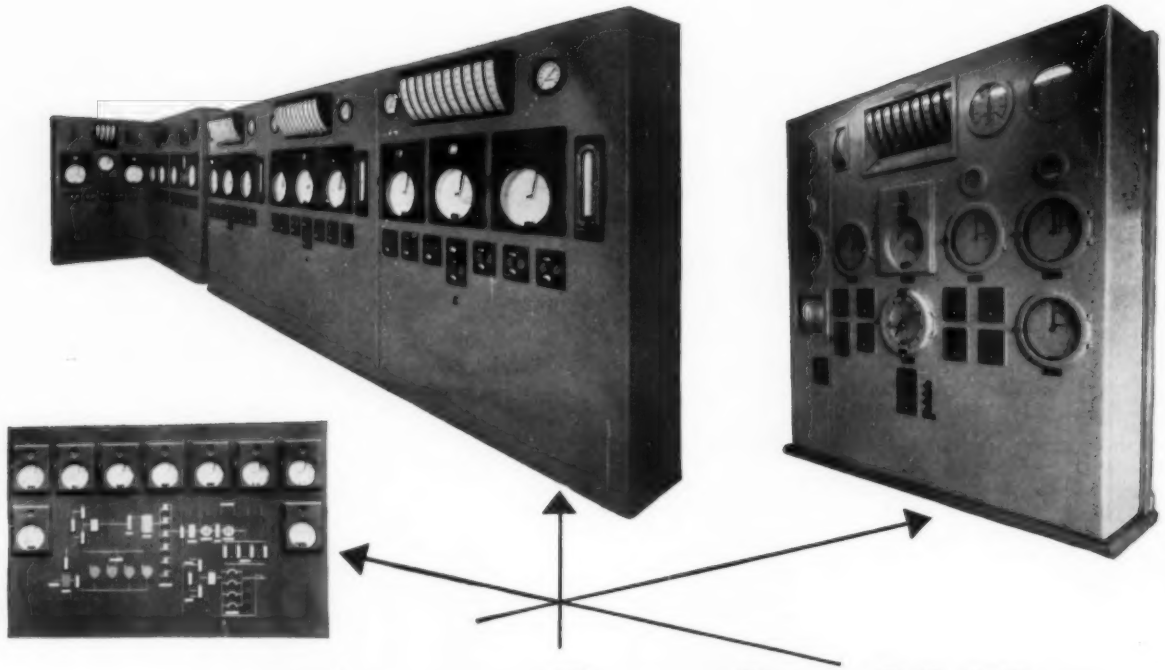

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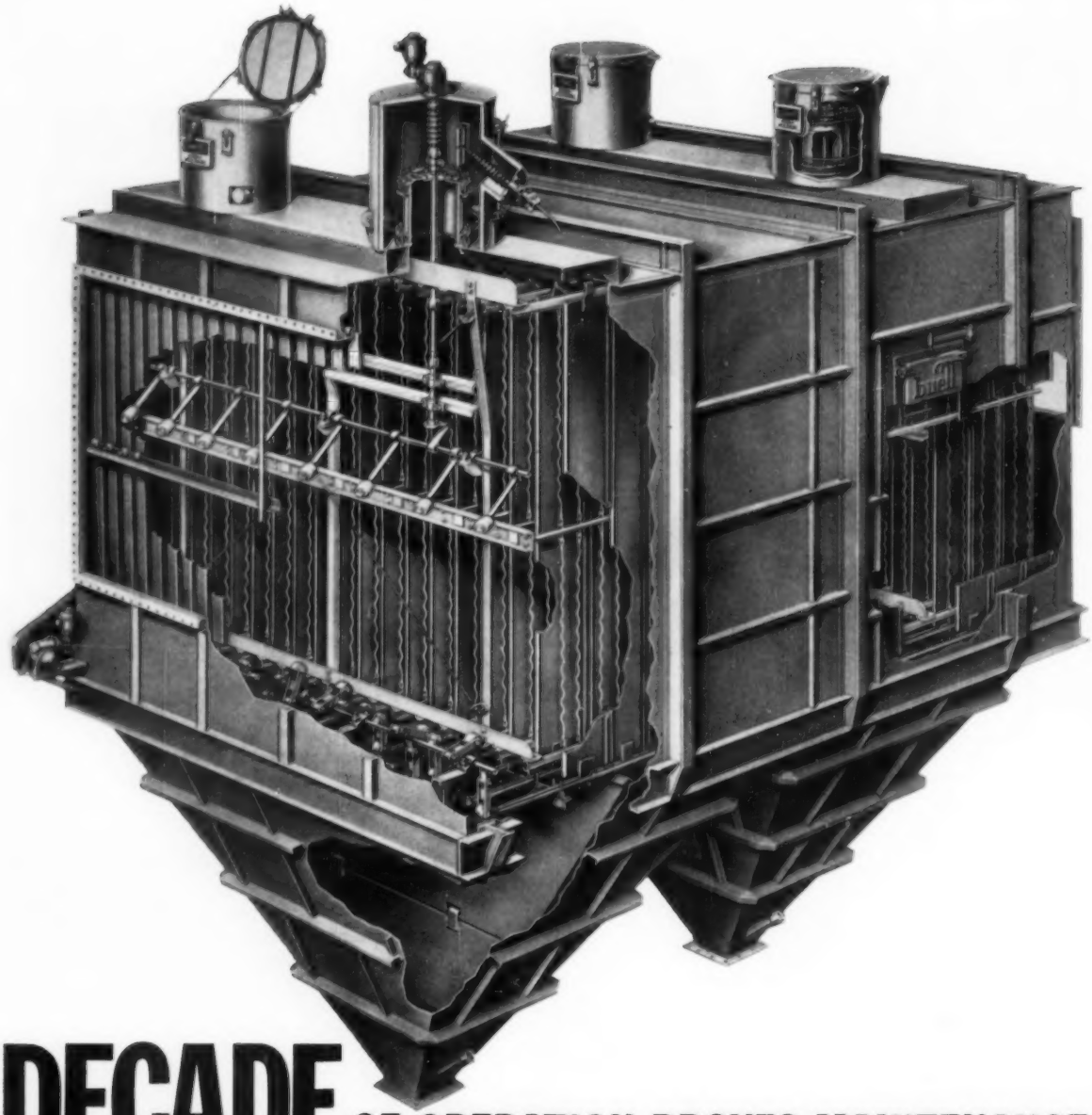

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Editorial

Breakthrough Ahead

About a year ago at the 2nd National Power Conference in Boston, E. H. Krieg, vice president and consulting engineer, Stone and Webster, spelled out in challenging terms the fact that we were drawing close to the end point for power generation along present lines. The physical needs, alone, of a plant built upon today's concept of good design would encompass a mile-square to house a 16 million kw station, which is the order of magnitude our expected future requirements will impose upon a generating installation. Obviously some new concept must be developed.

On page 42 of this issue a report is made on an imaginative attempt to achieve a breakthrough. This attempt, referred to as MHD, meaning magnetohydrodynamics, would employ a high temperature, high velocity, ionized gas stream passing through a strong magnetic field to generate electricity. The hoped for improvement in thermal efficiency envisions systems approaching 60 per cent against today's top of about 40 per cent! Truly alluring to the researcher's mind.

We attended a special press conference called to announce the decision of ten power companies and the Avco-Everett Research Corp. to pool funds to further the development of MHD. That conference produced the inevitable questions of timetables, comparisons with nuclear energy, anticipated costs. The Avco people were most enthusiastic on its imminence and spoke of a ten-year development span.

Philip Sporn, whom we regard as tough-minded, practical and yet visionary, pointed out the years still ahead for competitive nuclear power. He emphasized the inescapable facts that we are only beginning to accumulate the basic science for MHD much less its economic adaptability. If this approach, meaning MHD, should prove feasible within thirty years, in his opinion, a major advance in man's mastery of his environment will have been achieved. We share Mr. Sporn's views and with the rich possibilities of a 60 per cent thermal efficiency as the reward we can only add our small voice to that of the industry who wish them God-speed.

The present state of knowledge of high intensity combustion, liquid sprays, furnace aerodynamics, and flame stabilization is reviewed, and attention is drawn to the need for much further work in many of these fields of study to make the results of real value to the engineer. The use of model techniques and the performance of some types of burner are discussed and an indication is given of the importance of aerodynamics in the boiler furnace as a whole.

By A. M. BROWN†
University of Sheffield

Pressure-Jet Oil Burners for Boiler Use*

THE day is passing in which pressure-jet oil burners on boilers and in similar applications are operated with poor atomization of the oil and only a small pressure drop across the air register, often requiring large percentages of excess air for good combustion. Sometimes also little attempt was made to obtain a suitably shaped flame for the use required. In recent years efforts to obtain good atomization, attention to air register design and considerable increases in air velocities in the burner have resulted in much improved conditions of combustion. Today the range of burners in common use runs from the $^1/_2$ gph domestic unit using distillate fuels up to 5,000 lb/hr units firing preheated residual fuels with viscosities sometimes as high as 6,500 sec Redwood I at 100 F. The use of as little as 5 per cent excess air has been claimed for some well-designed burners and installations. Combustion intensities of 100,000 Btu/cfh atm and upwards are now common, and considerable improvements in performance have been obtained by increasing the draft losses employed across the air register at maximum load from the range $^1/_2$ to 4 in. w.g. to anything from 3 to 10 in. w.g. or higher in the bigger units. Pressure drops as high as 20 in. w.g. have been used in some high-intensity burners, and much higher still in jet-can combustors. Much more care is also being given to "fitting" flames to the more tricky applications such as shell boilers.

In the future the increasing demand for compact boilers, particularly for marine purposes, will necessitate higher combustion intensities and more stringent combustion conditions (see later, Fig. 3). In addition, economy and automatic operation will demand much greater knowledge and control of conditions in the flame at all loads. Although satisfactory results for many purposes are currently being obtained, there remains a very wide sphere for increased understanding of the combustion process, and for improved burner performance. This applies not only to the development of individual burners by themselves, but also to such matters as the interaction of adjacent flames and the aerodynamics of the combustion system and boiler as a whole. In the past, most methods of design have been largely empirical and the application of fundamental principles often neglected, although examples can be given of attempts to apply theoretical results to the parallel field of gas-turbine combustion chamber s(1–3).[1] Despite the large amount of development work which must have been done by individual manufacturers, it is much to be regretted that with few exceptions (4–7) very little on the subject has appeared in print.

In this paper the present state of knowledge of aerodynamic requirements and mixing processes in pressure-jet burners is reviewed, rather than the handling and atomization of the oil. It is presented in the hope that this will stimulate discussion, and assist in the development of improved combustion equipment.

Main Features Required for Pressure-Jet Oil Burners

The main requirements for liquid-fuel pressure-jet systems are:

(*a*) A high combustion intensity relative to the draft loss.

(*b*) A combustion efficiency (i.e., heat release compared with calorific value of fuel) of better than 99 per cent at maximum firing rate.

(*c*) Satisfactory flame stabilization, and optimum mixing of fuel, air and recirculation products.

(*d*) Satisfactory combustion over the specified turn down range (anything from 3:1 to 20:1). This is particularly important for automatic control systems.

(*e*) Avoidance of pulsations for any loading in the desired range of operation.

(*f*) Good heat transfer and combustion-chamber design.

(*g*) Tailoring of the flame to avoid damage to refractories or metal parts, especially the oil sprayer and air register, impingement on tubes or superheater elements, and avoidance of deposition of carbon or soot at any point.

* Paper presented at the Conference on "Major Developments in Liquid Fuel Firing—1948 to 1959" held in Torquay, 11th to 14th May, 1959. Printed by permission *Journal of the Institute of Fuel*, 18 Devonshire St., Portland Place, London W1, Sept., 1959.

† Department of Fuel Technology and Chemical Engineering

[1] Numbers in parentheses refer to similar numbered entries in the List of References at the end of the article.

Overall Theoretical Combustion Requirements

The first requirement is adequate heat transfer to raise the temperature of the fresh material to ignition point. There are several possible mechanisms, preheat, conduction or radiation back from the flame, or recirculation, but in the pressure-jet system only recirculation is really significant. Assuming small heat losses, a ratio of recirculated products to fresh combustion air of 0.75 is about the minimum for this purpose, and it has been shown experimentally that the maximum combustion rate per unit volume is obtained at a ratio of about 4.0. A further increase in combustion products dilutes the reacting mixture, and slows down the combustion rate. With the exception of units such as small domestic boilers, heat transfer to the walls is unlikely to be sufficient to quench the flame in the combustion space. Thus, provided the percentage of excess air is fairly low, incomplete combustion (i.e., low efficiency) can only result from insufficient time to complete the chemical and physical processes of combustion before the reacting mixture is cooled by the tube bank.

From investigation of ignition delay, Mullins (8) has predicted that the maximum combustion intensity attainable in a liquid-fuel spray should be as high as 3.9×10^9 Btu/cfh/atm. This figure is apparently only slightly affected by vaporization, droplet size, turbulence or air/fuel ratio, and is almost the same for all hydrocarbon fuels. Longwell's famous perfectly stirred reactor (9) has indicated that the maximum combustion intensity achievable by instantaneously mixing fuel, air and combustion products is 4×10^8 Btu/cfh/(atm)$^{1.8}$ with 80 per cent completion of combustion. Both these results indicate that chemical processes are extremely rapid, and that the physical processes of mixing and evaporation are mainly responsible for incomplete combustion in any ordinary oil-burning system.

Applying the results derived by Longwell to cases of more immediate interest, Bragg (10) has shown that for higher combustion efficiencies in non-premixed systems the greatest intensity is obtained when 85 per cent of the stoichiometric air is brought into the homogeneous reaction chamber, giving 20 per cent of the fuel unburnt at the exit. A second chamber is attached where further air, up to 16 per cent excess, is added. For 99.9 per cent efficiency this secondary chamber must be the same size as the primary one.

Thring and Masdin (11) have recently suggested that by mixing air stepwise down the chamber each time the reaction rate begins to fall off, even higher intensities could be obtained than in the homogeneous reactor. The effect of this system is compared with a Longwell type reactor in Fig. 1, the increase in combustion intensity being about 6 per cent. A good gas-turbine combustion chamber might approximate to something like this.

These results must represent the target for practical combustion systems. Bragg's result above, if translated into practical effect, would look something like the combustion chamber shown in Fig. 2. The Longwell results have been applied to gas-turbine combustion chambers by other workers (3) with some success. The conventional pressure-jet burner system is a long way from this ideal because the flame by no means fills the combustion chamber. The form of the oil spray used is also such that it is nowhere likely to approach a homogeneous mixture with the air, nor is it usually possible to have secondary air jets downstream of the burner as in the gas-turbine chamber. One advantage of a non-premixed system is that, with the correct aerodynamic arrangement, it should be possible to vary the local air/fuel ratio from distinctly rich at the entry to a weak final mixture, as in the Thring and Masdin suggestion, even without recourse to secondary jets. The exact understanding of the optimum course for mixing of fuel, air and combustion products still awaits experimental investigation, and this work is being undertaken by some of the author's colleagues. The theoretical work demonstrates nevertheless the great importance of obtaining the correct mixing pattern in the flame; this depends principally on the aerodynamics and is discussed in a later section.

By assuming that the combustion air velocity, and

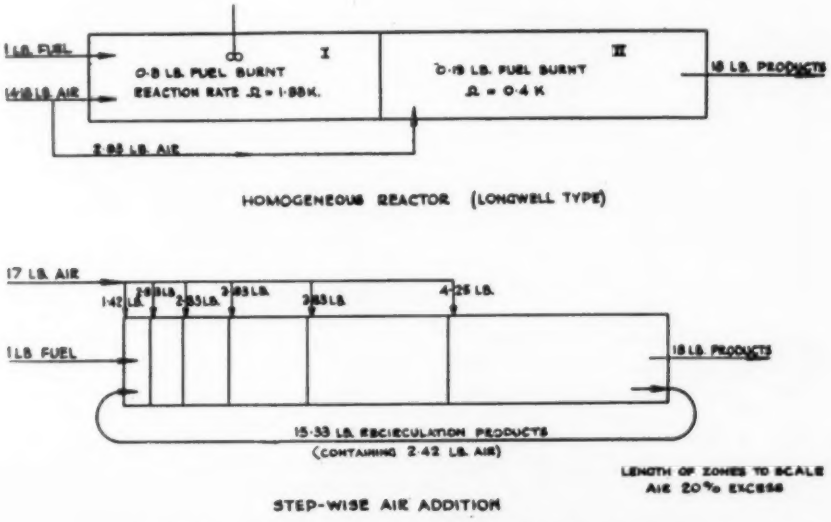


Fig. 1—Schematic arrangement of ideal high-intensity combustion systems

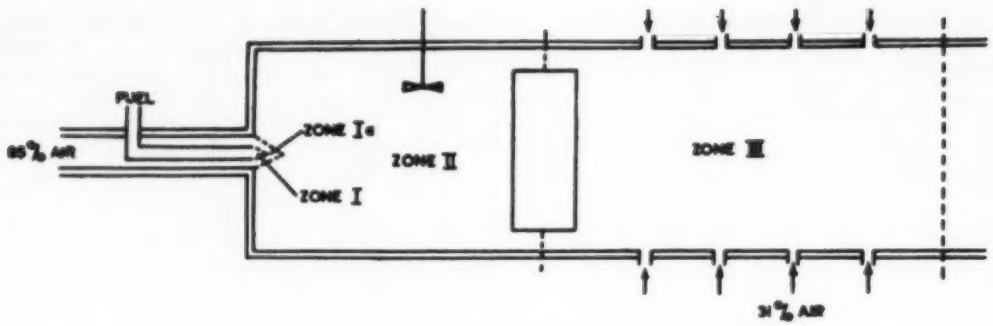


Fig. 2—An ideal non-premixed combustor for high intensity combustion

Zone I—Fuel mixing with primary air. Zone Ia—Fuel-air mixing with four masses of combustion products. Zone II—Homogeneous reaction zone. Zone III—Remainder of air mixed in a reaction proceeding from 80 per cent completion to 99.5 per cent completion.

hence pressure drop at the burner, is the principal factor governing mixing, a reasonable indication of how well practical systems approximate to the ideal can be obtained by plotting optimum combustion intensity per unit volume of the combustion chamber against absolute pressure loss (7). The homogeneous reactor lies at one extreme, and all systems lying on this curve represent equally good attempts to satisfy a different compromise. As shown in Fig. 3, real systems are often far from this optimum, which means that either they are wasting pressure drop for other purposes than mixing and recirculation, or else the combustion chamber volume is not being fully utilized. The line A represents the ideal, calculated on the assumption that the pressure drop arises entirely from the loss of dynamic head of the gases entering the chamber. Combustion intensity from this relation is proportional to $\sqrt{\Delta P/P}$ (where P is the total pressure and ΔP the pressure drop across the register). The curve B corresponds to Lubbock's empirical rule (12) where combustion intensity is proportional to $(\Delta P/P)^{2}/_{3}$. The actual points represent typical values from different applications and, as will be seen, the mean line C for these points is nearer to the relationship combustion intensity $\propto \Delta P/P$.

Fuel Spray

Turning from overall considerations to small-scale effects, the picture is far less complete. Fluid dynamic results for the behavior of moving bodies, the effects of drag, vortex formation, gas flow round obstacles under isothermal conditions and similar matters are discussed at length in the standard textbooks (13–15).

However, as a useful review by the Battelle Institute points out (16), our knowledge of hydrodynamics, evaporation of droplets and turbulence in combustion, for practical purposes, is extremely inadequate, and is further complicated by the differences in behavior between single particles and the dispersed systems of interest to the engineer. Any problem concerning droplets in turbulent combustion systems is bound to involve a large number of variables. Many of these are very difficult to determine experimentally, in view of the

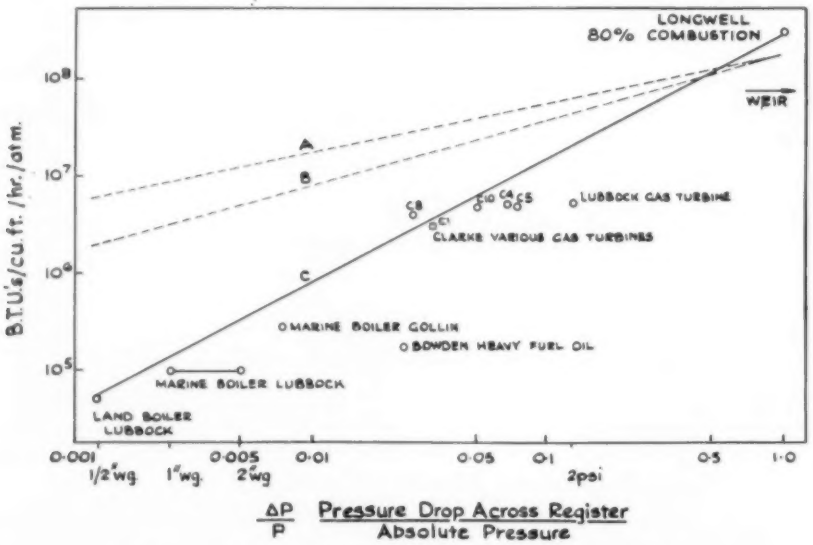


Fig. 3—Plot of values of combustion intensity against relative pressure loss for some real systems; also two suggested optimum curves for comparison

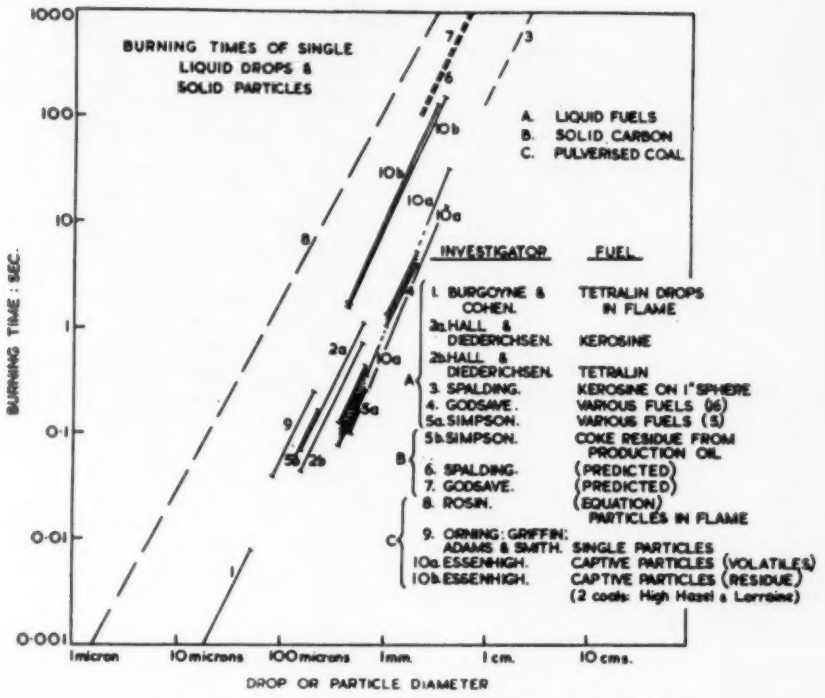


Fig. 4—Burning times of some single liquid drops and solid particles

problems encountered in establishing the precise conditions at any given point.

The behavior of single droplets has been established with some success. There is little agreement, on the other hand, about the paths described by freely moving particles, although satisfactory corrections have been produced for Stokes' law, notably by Langmuir (17).

The process of droplet evaporation for liquids of fairly low volatility is comparatively well accounted for by Frössling (18) provided that conditions are fairly uniform, although extension of this work to instances of high temperature and turbulence is badly needed. The relationship between heat and mass transfer, often treated as being virtually independent, also requires much more elucidation. For any practical calculations it is necessary to make rather drastic assumptions. Similarly for the calculation of droplet paths, it has been necessary to assume that the droplets behave as solid spheres, standard results for drag coefficients then being used (19, 20).

Disintegration of liquids and droplet distribution have been studied by many workers. Although no theoretical treatment has yet proved really adequate, the Rosin-Rammler distribution is one of the least tedious to use and gives satisfactory results. The upper limit function proposed by Mugele and Evans (21) gives a slightly better fit to the observed data, and, since it takes into account the finite maximum droplet size, is probably more reliable for the calculation of mean droplet sizes (16, 22–26). It is not the purpose of this paper to discuss the different types of pressure-jet atomizer or the theory behind them, and good reviews are available elsewhere (16, 24–26).

Droplet burning has been investigated both theoretically and experimentally by a number of workers (27–29), and this has given some insight into the combustion process. The droplet size is of real importance to the combustion process in two ways. First, the difference in penetration and dispersion of different size droplets is one of the principal ways by which mixing of air and fuel is effected, and also has some part to play in stabilizing the flame and establishing its shape. Second, burning times of individual droplets are the other physical limitation of combustion efficiency, and some typical results are shown in Fig. 4 (7). The importance of burning times, and hence fineness of atomization, can be gaged when it is remembered that for combustion intensities of 10^5 and 10^6 Btu/cfh/atm the mean residence time for droplets in a boiler is 0.6 and 0.06 sec, respectively. The long burn-out time for the carbon skeleton makes this fact particularly important for residual fuels. For boilers, a Sauter mean droplet diameter of 100 μ or less is regarded as essential. From the point of view of combustion intensity, it is also desirable that the aerodynamic arrangement should permit as few particles as possible to come out in less than the mean residence time.

Aerodynamics

Understanding of turbulence has always been hindered by the lack of a satisfactory physical picture, and by the failure to correlate statistical or empirical theories with observed phenomena (16). The effect of both small-scale and large-scale turbulence in combustion is to increase the mass transport and surface area of the flame, and has been used to account for the greatly increased heat release in a turbulent flame as compared with a laminar flame (3, 30, 31). In the combustion process the

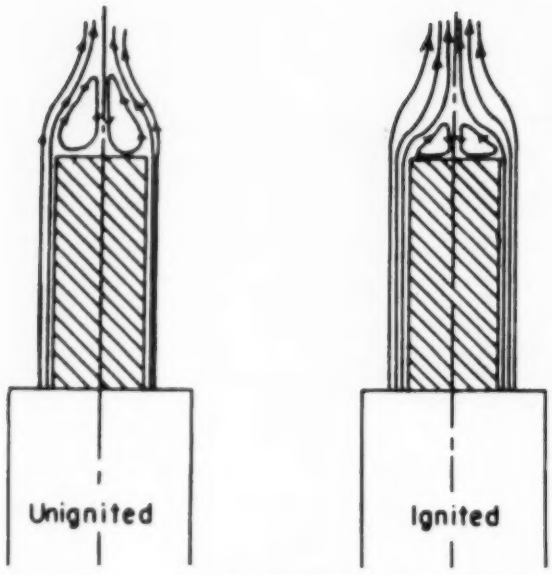


Fig. 5—Alteration of flow pattern round a flat-ended rod under unignited and ignited conditions

predominating effect is the combustion-produced large-scale turbulence, which is substantially greater than that due to the air flow alone.

All the theoretical methods for mixing in terms of mixing length give only mean results which are of little practical interest. The entrainment of air by free jets has been investigated in some detail (32), but so far nobody has succeeded in estimating the course of entrainment of gases by liquid-fuel droplets in a pressure-jet spray. This result would be of some interest in determining the necessary aerodynamics of the air surrounding the spray.

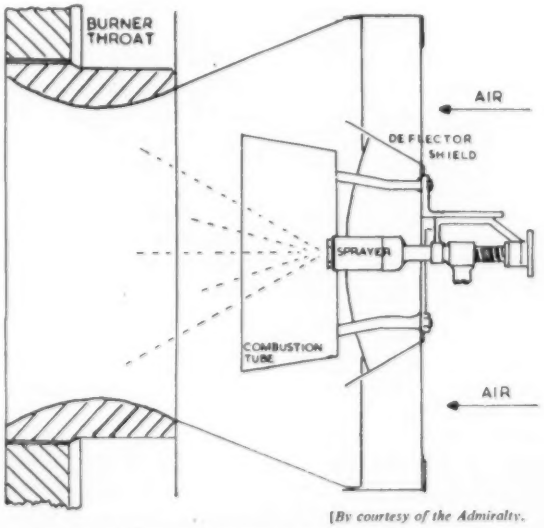
Even in simple arrangements flow patterns can be quite complex, and at the moment it is impossible to predict with any accuracy the aerodynamics of any practical burner unit. Nor, consequently, is it possible to predict theoretically arrangements that will produce the mixing pattern demanded by the combustion considerations discussed in earlier sections. Here probably most of all a great deal of work is needed, if only to produce some empirical rules and methods whereby the efficiency of a given arrangement can be estimated. One partial solution, suggested for gas-turbine combustion chambers, is estimated in terms of the refreshment of a recirculating vortex (19).

Most of the classical work on flame stabilization has been carried out for laminar premixed systems, and the application of the results to turbulent diffusion flames must at best be distinctly uncertain. In general, flame stabilization is achieved by establishing an eddy system behind a bluff body. Predictions of the efficiency of this for simple systems in terms of blow-off velocity have been made by a number of workers (33–36). An important practical consideration which must be kept in mind, particularly in the interpretation of cold flow results, is the very large alteration observed in flow pattern between isothermal flow over the stabilizer and the condition where the mixture is burning (see Fig. 5) (37).

The development of low-frequency pulsation, usually of the range from 3 to 40 cps, has been a serious embarrassment in widely differing types of boiler installation. The amplitude of these pulsations can at times be as great as the draft loss across the air register, and can result in a distinct alteration of the flame cone angle during each pulse. Putnam (38), working on small domestic boilers, has shown that this type of pulsation is non-acoustic, and has produced results indicating regions of instability without relating them to specific parameters of the combustion chamber or flame. The theory for "chugging" developed by Crocco and Cheng (39) has been successfully applied to rocket motors by Tischler and Bellman (40), and adapted to the case of conventional oil burners by Thring (41) and Fritsch (42). In essence, the theory depends on, as controlling factors, the restrictions in the system (e.g., at air register and stack), and postulates either a definite delay time between reaction rate variations and the consequent pressure variation upstream of the constriction, or an inertial effect of the fluid flow in some part of the system. For certain ranges of conditions this can result in the development of a stable feedback oscillation mechanism powered by the combustion process. There is some disagreement in detailed findings, but it is safe to say that for many installations there is unstable combustion at some range of loading, and that this is related, among other things, to the efficiency of mixing air with the burner fluid and the resistance to flow at the inlet and outlet. These factors are often easily modified, and this accounts for the fact that random alterations to the air flow through the register have often in practice cured the trouble. When this theory has been further developed, it should be possible to use it in designing boiler installations so that this trouble is avoided in the operating range.

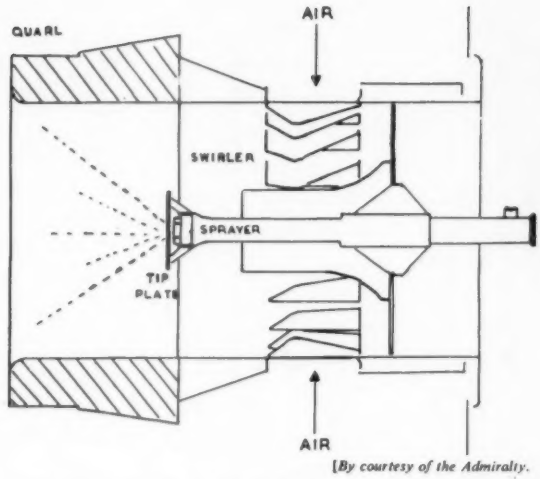
Practical Burner Systems

Although the results of work on flame stabilization reviewed in section 5.3 cannot be quantitatively applied



[By courtesy of the Admiralty.

Fig. 6(a)—1941-type Admiralty air register (impingement type)



[By courtesy of the Admiralty.

Fig. 6(b)—1943-type Admiralty air register with swirler and tip plate stabilizer

to pressure-jet systems, it illustrates the essential part played by eddies and recirculation in stabilizing the flame. All flames of this type are maintained in the desired position by the establishment of an equilibrium between the rate of flame propagation and the motion of fuel, air and combustion products. It must be remembered, too, that there will be quite large instantaneous variations in the flame, although it appears regular to the observer. Four typical burners and air registers are illustrated in Figs. 6 (*a*), 6 (*b*), 6 (*c*) and 6 (*d*). Each is stabilized by an eddy which is produced in Fig. 6 (*a*) by the downstream construction of the burner quarl, in Fig. 6 (*b*) by a flat baffle, in Fig. 6 (*c*) by a conical baffle with slots and swirl vanes, presumably to produce smaller eddies, and in Fig. 6 (*d*), which is a modern high-intensity suspended flame register, by a large swirler producing stabilizing vortices in the actual combustion chamber. The effect of the stabilizers used in Fig. 6 (b) and Fig. 6 (d) can be judged from Figs. 7 (*a*) and 7 (*b*), respectively, which are somewhat similar configurations obtained for gas turbines (19).

Mixing of the combustion air in the systems illustrated is achieved in several different ways, varying from directing the air into the oil spray at the quarl as in Fig. 6 (*a*), which is very sensitive to burner setting, to establishing a swirled-air cone round the spray in the suspended flame register illustrated in Fig. 6 (*d*). In this last instance, analogy with results obtained from a similar gas-turbine arrangement (20) shows how very sensitive the system is to shroud air flow round the atomizer and swirler angle. It appears to be easy to get a large vortex developing which carries the combustion air right away from the flame in the early stages, with consequent trouble from a secondary flame stabilized on the air register. Up to the present a study of the effect of swirl on mixing and flame configuration has only been undertaken for very limited fields (43, 44), and a much more general survey is badly needed.

Methods of design employed for air registers have in the past been as much art as science. There seems to be a wide field not only for the use of the criteria discussed earlier in this paper in the design of more efficient types of burner, but, in addition, for much greater understanding of the flow patterns required to obtain stabilization and good mixing. The obvious techniques for experimental work are scaled-down units and cold air and water analogs (45–47). The scaling of such widely differing parameters as combustion intensity, turbulence, droplet penetration and so on, especially in systems with complicated aerodynamics, presents formidable problems. This work is the special concern of the author's research. Many workers have regarded Reynolds' similarity as being sufficient. However, the suggestion made by Thring (45, 46) of allowing for the change of density on combustion by altering the scale of the inlet relative to the combustion chamber, is obviously a more correct approximation. This means that the model used is a model of a system with all gas flow at the flame density, but with the correct inlet mass flow and momentum. Any method of scaling is bound to involve more or less drastic simplifications, and the important results need to be checked on the prototype. Nevertheless, model techniques can result in big savings in time and work by providing the most likely solutions to try on full-scale work, and in clarifying the processes involved.

Very little consideration seems to have been given so far to the matter of gas flow through the boiler as a whole. The big differences in temperature distribution reported for both power-station boilers (48, 49) and marine boilers (50) indicate that the subject of aerodynamic design of boilers also requires study. This has been further emphasized by the study of flow patterns in a high combustion intensity marine boiler by one of the author's colleagues (51).

The interaction of several burners firing together, and the increase in pressure drop usually required when doing this, and such matters as the spacing and relative angle of groups of burners and the effect of opposed directions of swirl, are all problems the answers to which would

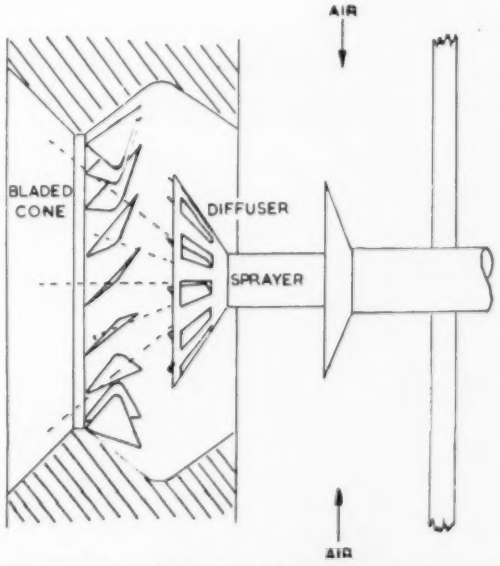
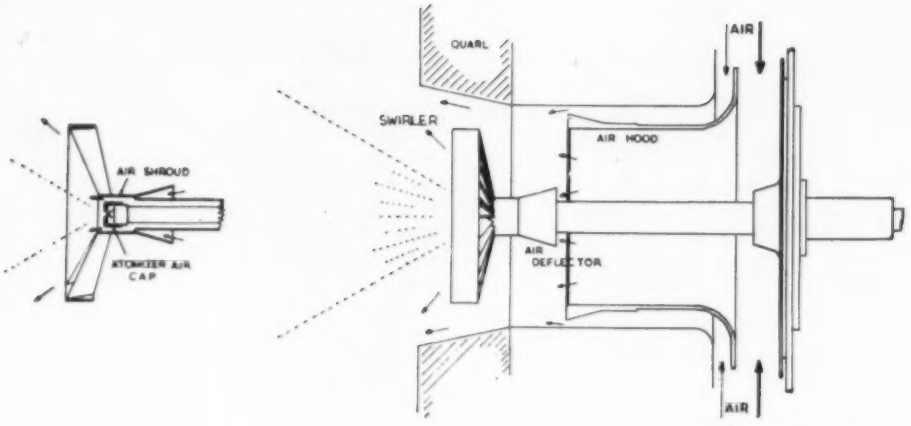


Fig. 6(c)—Babcock and Wilcox Carolina air register with conical diffuser and swirl vanes (some detail omitted)

By courtesy of the Admiralty



[By courtesy of the Admiralty.

Fig. 6(d)—Modern high combustion intensity suspended flame air register

be of considerable interest. To mention a few specific examples, the heat transfer differences of up to 6 per cent for different groups of burners running at the same load (50), recently reported, have emphasized the importance of correct burner arrangement. Gollin (4) has recently drawn attention also to the need for evaluating different arrangements of burners in power station boilers; some possible arrangements are shown in Fig. 8. This last problem is one in which cold model techniques would be particularly applicable.

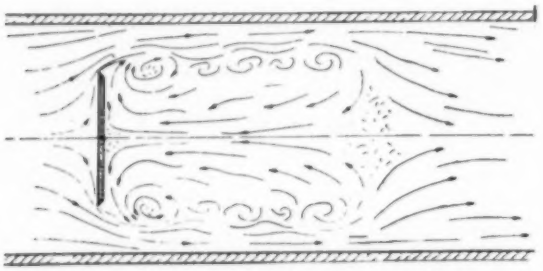


Fig. 7(a)—Flow patterns in gas-turbine combustion chambers: eddies and flow reversal behind flat plate stabilizer.

Conclusions

In general, modern trends are toward higher combustion intensities, larger turn-down ratios in conjunction with automatic control and more efficient systems. The achievement of good mixing of fuel, air and recirculation products at all rates of firing requires the application of fundamental research to a much greater extent than has been done in the past, for the improvement of existing burners and the development of new types. The development of satisfactory model techniques to speed up this work is also important, and the application of analogs similar to the one-twelfth scale water model shown in Figs. 9 (*a*) and 9 (*b*) should provide a valuable tool at the drawing-office stage of the design of boilers and similar installations.

Acknowledgments

The author acknowledges with gratitude the advice and encouragement of Prof. M. W. Thring and other members of his department. He is grateful also to the staff of the Admiralty Fuel Experimental Station; G. J. Gollin, B. V. Poulston and J. R. Joyce, of the Shell group; the staff of Joseph Lucas (Combustion), Ltd., Birmingham; and I. Bowen, of International Combustion (Derby), Ltd., for useful discussion during the preparation of this paper. Thanks are also due to the Admiralty for financial support for the project on which the author is working.

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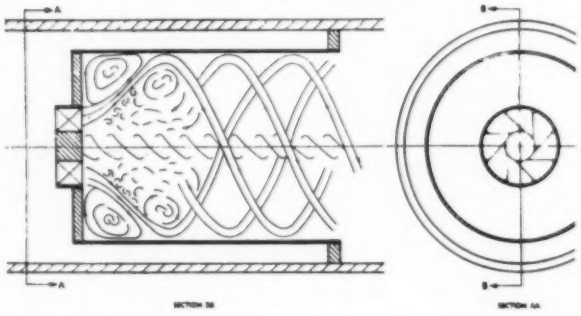

Fig. 7(b)—Flow patterns in gas-turbine combustion chambers: recirculation vortices produced by an air swirler.

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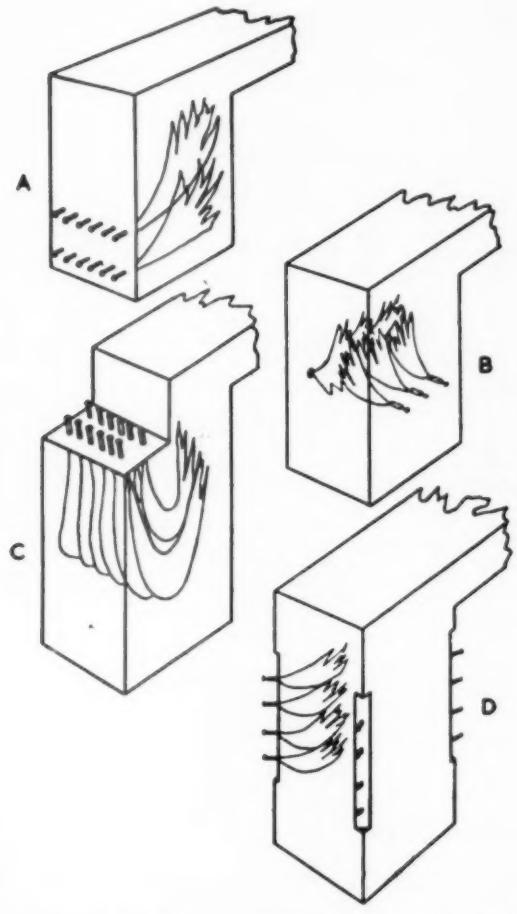

Fig. 8—Four possible ways of installing oil burners for a large power station boiler

A, on the front wall. B, on side walls firing opposed to each other. C, on the roof firing downward. D, at the corners.

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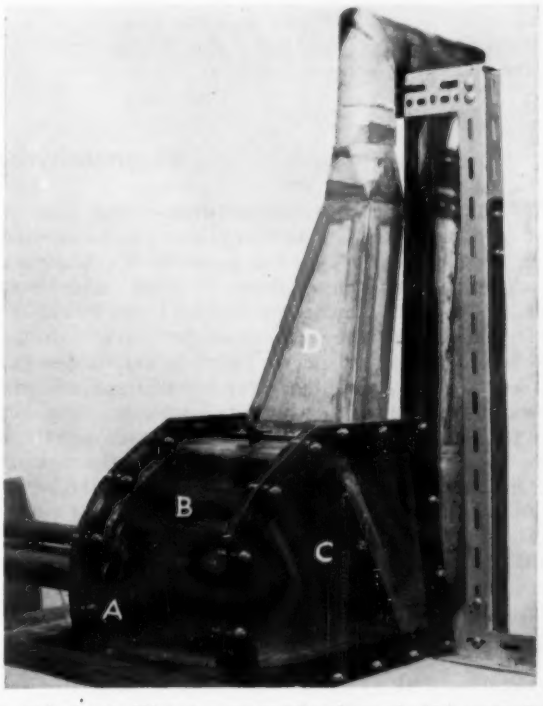

Fig. 9(a)—One-twelfth scale water model analogue of a high combustion intensity marine boiler

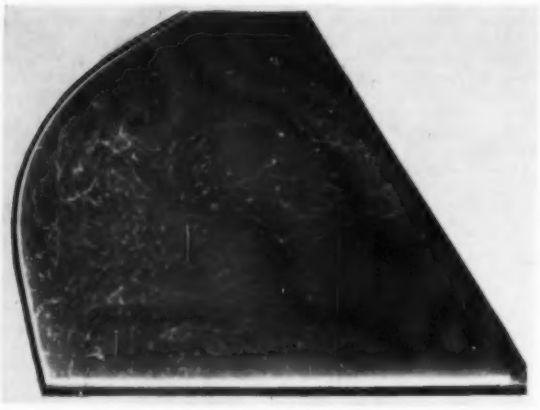

Fig. 9(b)—Typical flow pattern obtained in this type of model, using polystyrene particles as flow indicator. In this instance the illustration shows a narrow plane one scale ft from the back wall of the analogue, with one burner in use

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Magnetohydrodynamics (MHD)

THIS imposing word describes what appears to be the first real break-through in power generation since Thomas Edison harnessed James Watt's thinking to produce electricity on a commercial scale. The ionization of gases at elevated temperature (3000 F–5000 F), which allows the gases to conduct electricity, is the key to magnetohydrodynamics. In an MHD electric generator, ionized gas (substituting for the armature of a conventional generator) passes through a magnetic field and generates direct current which is tapped directly off the stream of hot gas.

In the open cycle, a fossil fuel is burned in high pressure, high temperature air. Combustion gases seeded with vaporized metal to enhance ionization flow through an MHD generator producing direct current and then continue through the regenerator, superheater and boiler. Steam is used in auxiliary turbines to drive the air compressor and to generate power.

Closed cycles using either chemical furnaces or nuclear reactors will also be investigated under a research program undertaken last month by Avco Corporation in conjunction with ten of the nation's leading power companies. With either type of heat source the very high thermal differential betweeen source and sink is the prime factor leading to higher thermal efficiencies. It is the tremendous increase in cycle thermal efficiency that classes the new approach as a major breakthrough in electric power generation. In recent years the increase of cycle efficiency has been a slow, painful and costly process. Now we have MHD offering thermal efficiencies up to 60 per cent. This is in marked contrast to the 40 per cent achieved by the most efficient of our modern steam turbine plants.

The outlook is bright indeed but one cannot ignore the years of development work required before the first practical commercial MHD generating station can go into service. One of the most critical areas for research and development in MHD is the direct generation of alternating current. MHD researchers have hope in this direction but no definite ideas as yet. The ability to generate AC directly is expected to bring about capital plant cost reductions up to 20 per cent. At present the estimated capital cost for an MHD plant of 450 Mw is about equal to the projected cost of a conventional plant.

THE August 1959 issue of COMBUSTION reported a question and answer session on "Water Side Boiler Tube Failures—Their Origin and Treatment," featuring Dr. R. C. Ulmer, Combustion Engineering, Inc., manager of research. It was acknowledged at that time that the remarks constituted one man's opinion and the views of others were sought. These other views prompted by the more provocative of Dr. Ulmer's comments we print below.

Boiler Tube Failures—An Open Question

WATER TREATING COMPANY PARTICIPATION

Dr. R. C. Ulmer: *"The water treating company cannot contradict the boiler owner who hires him so he also blames the boiler."*

E. P. Partridge
Hall Laboratories

"It would be pretty silly for the managers of the many major utility companies and the many large industrial plants who now retain the engineering services of recognized water treating companies to spend good money just for yes-men. And it would be pretty silly for the water treating companies to try to build their consulting service by providing only nods of assent to those who are paying for the best technical recommendations.

"In my opinion it is not bad that 'the major boiler manufacturers have been forced to, in effect, operate water treatment departments.' In our field water conditioning. we have found that we could not properly discharge our responsibilities without studying fluid flow and heat transfer. Out of intelligent discussion between people capable of understanding each other's concepts has come most of what we regard today as good engineering practice."

I. B. Dick
Consolidated Edison Co.
of New York, Inc.

"Water treating companies are generally retained by operating utilities, frequently in the capacity of consultants to the utility's own chemists. Several of these companies have national or international practices, and a very few of them serve most of the biggest boilers in the country. Because of this broad coverage of all makes and types of boilers, they feel they have superior knowledge, based on experience and upon their excellent modern technical facilities. Their personnel have been outstanding in introducing and sponsoring almost all modern developments in boiler water and feedwater treatment except coordinated phosphate-pH control. These water treatment companies have weathered the storms of hysteria which accompanied nitrate treatment, sulfite, hydrazine, coordinated phosphate, 'zero' treatment, dispersive colloids and many others. They have been good blance wheels for the utility industry. They have, in general, approached their problems from a dispassionate scientific viewpoint. It has been our experience that our water consultants have no hesitancy in differing from us and in recommending changes in treatment and even in basic philosophy of our water treatment when they feel they have adequate justification. Your paper implies their advice and 'thinking' are biased by their clients' wishes, which in my opinion is grossly unjust and unjustified.

"Boiler manufacturers, it must be remembered, are in a highly competitive field. Their customers, who cannot possibly know as much about boiler design as the manufacturers, usually buy on price based upon some sort of a 'specification' that the customer has prepared. The terms of

this specification are so loose that the manufacturer has wide latitude in design. Furthermore, the manufacturer's guarantee on his boiler cannot be any more liberal than that of his competitors, since all are prescribed by the ABBMA Code, which is admittedly archaic and inadequate. Therefore each boiler manufacturer, in order to be competitive, takes full advantage of the looseness in the customer's specifications and the inadequacies of the Code, and offers the cheapest boiler he can. The result has been the fabrication of many boilers that will not tolerate the water that the customer has in his system. The boiler manufacturer thereupon attributes all the troubles to water chemistry, although he was fully aware of the customer's water chemistry at the time he contracted to sell the boiler."

T. Finnegan
Niagara Mohawk Power Corp.

"Larger companies, including most utilities, have their own specialists who watch the water analyses and supervise the water treatment processes as well as investigating problems of scale and corrosion and making the decisions concerning them. Frequently they also use the services of a water treatment company. In this case the latter does not supervise the work but instead functions as a consultant and a source of information which it is qualified to do because of its wide coverage of the field and sometimes by its research facilities.

"On the other hand, when trouble such as tube failures occurs, they are brought to the attention of the boiler manufacturer whose wide experiences with boilers of many types enables him to offer suggestions from his point of view. If the boiler manufacturer has a water treatment department he is better prepared to make the suggestions authoritative.

"All three groups are represented on the Joint Research Committee of the ASME to which Dr. Ulmer refers and this gives potentialities to that committee which would not exist if any of the three were absent."

R. T. Hanlon
Alchem Limited

"This is a very general statement and is essentially untrue. Any qualified engineer engaged in water treatment practice realizes that certain optimum conditions of feed and boiler water composition must be maintained to prevent internal boiler deposits and the boiler owner is always so advised. To blame the boiler manufacturer would serve no useful purpose, when poor water treatment practice and/or control is the cause of these deposits.

"In some instances where complex scales such as analcite or acmite are formed within boiler tubes, the boiler manufacturer is consulted not only by the boiler owner but as well by the water consultant. This does not imply that the manufacturer is 'blamed.' In most cases the owner or the consultant is only seeking information which may be of help in solving the problem, and in a number of cases, at least in the experience of the writer, minor changes in design have been highly effective in this connection.

"It has been our experience, as well as that of a number of boiler owners, that boilers are sold with certain provisions in the guarantee concerning boiler water composition in connection with the maintenance of specified dissolved solids, suspended solids and total alkalinity concentrations, when it is realized at the time the contract with the boiler owner is executed, that such provisions cannot be met with the type of makeup water then available.

"If a qualified water consultant is asked for his opinion at such time the boiler owner would be properly advised and recommendations made for the installation of makeup water preconditioning equipment to provide a boiler water which would meet the boiler manufacturer's specifications. Unfortunately, in too many cases, the water consultant is not hired or advised until shortly before the boiler is placed in operation.

"Then, if carryover occurs both the boiler owner and the water consultant are faced with meeting boiler water specifications imposed by the boiler manufacturer without the installation of proper water pretreatment equipment necessary to meet such specifications.

"Would it not be better practice in these instances for the water treatment department of the boiler manufacturer to advise their customer in this connection, since such would eliminate considerable subsequent difficulties and misunderstanding?"

V. J. Calise
Graver Water Conditioning Co.

"My thought in reading this and other articles over the past twenty years is that while we must always strive for better methods through self-criticism and analysis, we must nevertheless keep in mind that the lowest heat rate and largest thermal plants in the world are still being designed, installed and successfully operated by the U. S. power industry.

"I must also point out that, as a designer and manufacturer of equipment used to purify makeup feedwater and condensate in these high pressure cycles, the responsibility which we as an industry bear has mainly to do with the performance of this equipment in meeting its prescribed chemical and mechanical guarantees. We also observe the effects of a wide variety of treatment and water purities on boilers and turbines in various high pressure cycles. We feel strongly that the quality of the technical assistance and services rendered to the power generating industry by boiler manufacturers, water treatment and consulting engineers specializing in this field is of the highest order and far superior to what we have seen in European or Russian practice.

"It is also important to bear in mind that there has been a great narrowing of problems in this industry within the last 10–15 years. The various groups operating in this field such as the Joint Research Committee of the ASME, the EEI, ASTM, and the generous policy of the industry itself in promoting the sharing of information between companies, have been very helpful in this regard as has the help of manufacturers of equipment and consulting engineers.

"However, it seems to us that the power generating industry itself has not always been quick to appreciate or properly use all the information available to it for solving its difficulties. This may be due to the fact that the men involved in this industry are primarily mechanical engineers who have not always understood the profoundly *chemical* emphasis in manpower, organization and facilities required to be able to properly handle high pressure boiler plant problems. Another point is the one made that the design of a properly operating 'foolproof' high pressure plant requires an attitude to totality in viewing the selection not only of boilers and turbines and makeup treatment equipment but of all other components in the cycle in order to avoid corrosion, leakage, deposits and other problems. Although the power plant chemist and chemical engineer has been given great latitude and assistance in many utility systems in recent years, much more can be done to improve their capability of serving the industry more effectively."

Tube Failures

Dr. Ulmer: "*. . . Rather, thinning of the tube from attack by concentrating boiler water salts in the deposit is the common type of failure. In such cases metal temperature may only be a few degrees over that which would exist when no deposit is present. However, this is sufficient to cause concentrations of boiler water to several per cent strength and if free caustic is present rapid attack and possible embrittlement of the tube can occur.*"

E. P. Partridge
Hall Laboratories

"Because engineers accomplish desired ends by a change in technology faster than they can fully comprehend all the new facts relating to the change, they must always use not only facts but to some extent opinions. Dick Ulmer is entitled to his opinions; he should know it to be a fact, however, that internal attack of wall tubes as similar as the proverbial three peas in a pod has occurred in various high-pressure, high-temperature, high-capacity boilers in which the water: (1) contained free caustic, with a pH of about 11; (2) contained no free caustic, but only the captive alkalinity of coordinated phosphate-pH control, with a pH of 10.0–10.5; (3) contained no more than 1–2 ppm of all dissolved substances, with a pH of about 8.5. Each of these chemical environments has proved capable not only of gouging away the steel, but also of developing severe hydrogen damage in the remaining metal.

"Since caustic could scarcely have been responsible for the attack in the latter two cases, we have to say that some other factor or combination of factors can cause the same kind of damage for which we have been accustomed to blame caustic. Since our organization has probably empha-

sized the possible dangers as well as the probable benefits of caustic in more technical papers than anyone else, we are concerned with the current tendency to force caustic into the unvarying role of unmitigated villain assigned in the past to dissolved oxygen. Remember when every failure in a wall tube was attributed to dissolved oxygen?

"Dick Ulmer has noted that water treating companies do not all recommend or use the same treatment. We would like to emphasize that any one engineer of our staff actually makes different recommendations for different boilers, in the same way that a physician tries to treat the individual patient rather than an unreal standardized 'average man.'"

I. B. Dick
Consolidated Edison Co.

"The boiler owner, since the advent of the first high pressure boilers, has heard the same tune: "It is your water chemistry." However, the words change from time to time. In 1938 it was mostly failure to supply proper quality of makeup water and failure to maintain adequate internal treatment. In 1948 it was almost entirely dissolved oxygen that was entering with the feedwater, passing through the economizer without reacting, getting through the drum without escaping into the steam, passing through the downcomers without reacting, and waiting until it was halfway up a wall tube before it bit a hole in an otherwise good boiler tube. By 1958 this is all gone and forgotten and all the trouble is due to caustic soda which concentrates under sludge blankets and bites holes in boiler tubes. At various times we have been told to: Keep up the alkalinity, keep up the phosphate, add sulfite, add morpholine, add ammonia, add hydrazine, and now cut out the alkalinity and reduce the phosphate. During all these years we have been regaled with tales of how others have solved problems identical to ours by some combination of the above nostrums. To take one instance: A few years ago one of our boilers had an epidemic of tube failures in the screen tubes of the superheater arch. These failures were all in double bifurcates; four tubes originating from one nipple from the lower water wall header. Our diagnosis said too little water. We were assured by the boiler manufacturer that the entire trouble was dissolved oxygen in feedwater which was reacting in the feedwater system (note the change signals here) forming iron oxide which in turn precipitated in the arch tubes and caused overheating, caustic attack and ultimate tube failure. It was recommended that we tighten up on our deaeration practices and add an oxygen scavenger and a volatile alkaline chemical to our feedwater. Three other utilities were cited as having solved similar problems by these means. We agreed to tighten deaerating practices as good housekeeping. We also sought information from the three other utilities named. In each case we were assured the solutions to their problems were purely mechanical, and that no change in chemical treatment had been made or was contemplated. In our case, the second set of bifurcates was removed. Time may prove this was the solution to our problem. Incidentally, removal of the second set of bifurcates did not increase superheat temperature or stack losses as had been feared in some circles.

"We have boilers built in 1941 that have excellent records of tube failures in spite of extremely high heat releases and of direct flame impingement on wall tubes. In the same station, and operating on the same water with the same chemical treatment, we have other types of boilers, also built in 1941, that have had their entire furnaces rebuilt because of corrosion. We have a boiler built in 1951 that has never lost a tube, and we have a boiler built in 1953 that has lost almost 200. All these boilers receive and always have received identical chemical treatment. We have two identical boilers side-by-side in the same station, one with a good tube failure record and one very bad.

"Why? We don't know. I believe it is because of circulation rates and heat distribution and release. Design factors have been so skimped that boilers operate mostly on the narrow edge of perdition. Very small differences in operation are critical. Drums cost money. To keep drum size down, circulation is reduced, so there is less circulating water to be handled and to be separated from steam. This means fewer downcomers, smaller headers, and fewer steam delivery tubes. The boiler becomes

I. B. Dick
Consolidated Edison Co.

cheaper all around. Then to cap the climax, the operator will probably try to run it at 110 per cent of nameplate rating. And when failures result, water treatment is blamed.

"Recently we have heard a great deal about 'zero' treatment, which is the use of volatile chemicals only. Although your paper indicates this was a development of the once-through boiler, I think its actual practice far antedates that. It has been widely used, and in some cases abandoned. The current upsurge seems associated with two controlled circulation boilers in a utility power plant which had such a severe carry-over problem that the operators tried zero treatment as a gamble because it was the only livable condition for their turbines. The zero treatment worked and has subsequently been extended to other boilers in that utility's system. That it is not a cure-all for tube failures is proved by the fact that certain of the boilers so treated developed severe tube failure histories.

"We are now being importuned to use low-range coordinated phosphate-pH control in our new controlled circulation boiler scheduled to start in 1960. The record shows that boilers operating on the coordinated phosphate system have not been free from tube failures due to internal corrosion. Furthermore, our history discloses that condenser leaks occur with some frequency, and that free caustic alkalinity is desirable to condition properly the magnesium sludge formed from the salt water inleakage.

"That we are not hide-bound or wedded to our conventional treatment is demonstrated by our recommendation for a trial coordinated phosphate in a unit where we thought it justified. This recommendation, by the way, originated from our water consultant. Furthermore, we are planning to operate our nuclear plant at Indian Point with 'zero' treatment, which is revolutionary, and so far as I know is pioneering in a large power reactor.

"All of this discussion of water treatment overlooks the obvious fact that steel and water react to form iron oxide and to liberate hydrogen. All high pressure boiler steam contains hydrogen. All high pressure boilers, regardless of water treatment, contain iron oxide. Part of this iron oxide is formed in place, as proved by a hydrogen balance on the boiler. Our analyses of chemical cleaning operations indicate that at least four times as much iron oxide forms in the boiler as is carried in the feedwater. The rate of reaction of water and iron is a function of temperature. If we accept the old rule of thumb that the rate of reaction doubles for every 10 C (18 F) temperature rise, then a 200 F rise in tube temperature, which is metallographically undetectable, accounts for some 2000 times acceleration in corrosion rate. And here we run into a blank wall. What causes such increases in wall temperatures? We do not know for certain. Sometimes we find patches of scale or 'barnacles' in a tube, but what caused the barnacle to start at that exact point? Sometimes we find a thin, hard, dense mill scale. Sometimes there is nothing tangible. You may say the basic trouble is iron oxide carried in with feedwater. I ask you if you can give me any reasonable proof it was not a steam blanket brought about by sluggish circulation and local areas of high heat input. It may be that caustic soda, concentrating under a steam blanket or under a patch of scale, will speed up corrosion, but surely you cannot say that corrosion will not occur without caustic soda. It is a fact that 'zero' treatment boilers we have seen show corrosion and are black with magnetite, apparently formed in place. And I have seen no proof that caustic soda is necessarily an accessory to rapid corrosion and failure; but I have seen excellent evidence that generously designed boilers will operate for many years without tube failures even though they have always been treated with caustic soda."

J. M. Decker
The Detroit Edison Co.

"I am very much interested in the discussion of boiler water treatment for high-pressure boilers. My organization's chemical people agree that high caustic alkalinities should be avoided in order to minimize attack of tube metal under deposits by concentrated boiler water. In order to avoid high caustic alkalinities we have maintained coordinated pH-phosphate control of water in boilers operating from 800 to 1800 psi with consistently good results. In one 2000-psi boiler this treatment has given satisfactory results also.

J. M. Decker
The Detroit Edison Co.

"The coordinated pH-phosphate control used consists of maintaining the

pH	10.4 to 10.8
Phosphate, PO_4	40 to 60 ppm
Hydrate, OH	±5 ppm

"In another 2000-psi boiler it was impossible to keep 40 to 60 ppm of phosphate in the boiler water. The exact reason has not been determined as yet. The treatment then was modified to

pH	10.0 approx.
Phosphate, PO_4	5 to 15 ppm
Hydrate, OH	0 to 3 ppm

This treatment has given very satisfactory results for the past two years.

"We have two 2400-psi boilers in which we are maintaining both low hydrate and phosphate concentrations. One of these boilers has been operating satisfactorily for approximately one year; the other for a few months.

"I am not in favor of operating boilers that have drums and steam-purifying equipment with so-called zero or volatile treatment. It seems to me that by using those treatments one of the principal advantages of drum-type boilers is being lost. The drum is a costly part of a boiler and should be used to the very best advantage possible; one advantage being that the drum provides a place for separating steam from boiler water containing salts that are added to or enter by way of condenser leakage. Once-through-type boilers lack this advantage. Usually, however, polishing demineralizers are provided in the feedwater circuits to compensate for the advantages lost by eliminating drums. Sulzer-type boilers are a compromise between the drum-type and once-through types, possessing some of the advantages of each.

"I contend that (1) if one does not want to use boiler water treatment, he should buy boilers without drums (once-through type) and use part or all of the money saved for buying feedwater polishing equipment; (2) if one has a boiler with a drum and steam purifying equipment in which water treatment salts, even in very low concentrations, cannot be maintained, steps should be taken to correct the condition."

Iron and Copper Corrosion

Dr. Ulmer: "*Metallic oxides of Fe and Cu usually originate in the preboiler system.*"

J. M. Decker
Detroit Edison Co.

"Similar statements have been made elsewhere. There seems to be little question regarding the correctness of the statement as applied to copper. Since in most cases boilers have no structural parts made of copper or copper alloys, obviously, the copper and copper oxide in deposits must be carried into them by the feedwater. They are corrosion and erosion products from the condensers and feedwater heater tubes. The source of the iron oxide is not as obvious. It can come either from within the boilers or from the feedwater systems. My opinion is that the most of it comes from within the boilers and normally only a small part is carried into boilers by the feedwater.

"During the past few years, we have cleaned copper from boilers on 13 occasions after service periods ranging from 6 months to 6 years. Two copper removal methods have been used, the ammonium hydroxide-bromate and the hydrochloric acid-complexing agent techniques.

"Iron oxide also was removed from these boilers and from three new boilers that had produced no steam or very little prior to cleaning. Data from these experiences lead to the conclusion that of the amount of iron oxide removed by chemical cleaning only a small part was carried into the boilers by feedwater and that most of it formed at the surfaces within the boilers.

"I would like to point out that I am now trying to de-emphasize the importance of keeping iron oxide concentrations in feedwater at low values, since I feel that anything in feedwater that contributes to deposits on boiler heating surfaces should be avoided if possible."

V. J. Calise
Graver Water Conditioning Co.

"We agree with Dick Ulmer that generally, the makeup feedwater purity available from evaporators or demineralizers for treating 0.5–1 per cent of the total feedwater flow is satisfactory for the high pressure, drum-type blowable boiler plant. In the main, such plants in the 1800–2400 psig range have had little or no difficulties when properly designed in a 'total cycle' sense, with: (*a*) proper condenser and heat exchanger design, (*b*) proper materials of construction, (*c*) a closed, fully deaerated cycle with main heater and/or condenser deaeration, (*d*) proper drainage and venting of stage heaters, (*e*) ample low solids, low silica cooling water available, (*f*) proper internal chemical treatment, (*g*) controls and precautions to be taken as noted by Dick Ulmer. However, it has been clear to many in the industry for quite a few years that even with a drum-type, blowable boiler and a 'tight' cycle, at pressures above 1800 psig, serious problems of Fe and Cu corrosion can be encountered sometimes together with turbine blade silica deposits plus the requirements of higher blowdown and higher makeup to maintain TDS and SiO_2 in proper range for continuous high load operation.

"It has seemed to us that the tools of internal chemical treatment and extreme external makeup water treatment purity (only 0.5 to 1 per cent total evaporation), even with good cycle design and proper materials and equipment selection, are not always enough to permit complete and positive internal cycle control of impurities in the feedwater in many high pressure plants. Apart from the variations of applied chemical treatments in such plants, such problems exist where very high solids or brackish cooling waters are used as in the case of seacoast area plants, or in plants where the cooling water contains high siliceous or other turbidity or organic matter. Impurities introduced into the cycle through vents, drains and condensers and makeup have been estimated to cause up to 1 per cent thermal efficiency loss in the overall cycle over the initial 3–5 year high load operating period. Furthermore, the generally long period of startup before high load is attained which is characteristic of all plants above 1800 psig, regardless of cycle chemical cleaning method, due to the need for removing slow leaching or slow equilibrizing impurities within the cycle, takes its toll in low efficiency. It does not take much condenser weepage or leakage to appreciably affect the pounds of solids added to the cycle, regardless of extreme makeup water purity.

"There is still no commercially proved method of removing Fe and Cu from the feedwater at a point just ahead of the feedwater introduction into the boiler at temperatures above 300 F. High-rate filter, mixed bed scavengers treating all or a portion of the condenser pump discharge produces total solids on the order of 30–50 parts per billion and 3–5 parts per billion of suspended solids, 5 parts per billion of SiO_2 and other impurities, or what we in the industry now call ultra-pure water.

"It would be pertinent also to mention here that in line with Dick Ulmer's zero treatment prescription and the *total* look at all components in a cycle when designing a plant, more and more utilities in the European area, and now in the U. S., are evaluating and using steel tube stage heat exchangers, steel tube in evacuation sections of condensers to avoid copper corrosion product pickup, and high ammonia-hydrazine treatment at a pH of 9.5. In many plants with high Fe and Cu pickup, it may be of great advantage to have available a high temperature filter to remove Fe and Cu at some point above the low pressure stage heaters and as close to the boiler as possible. Tests with our millipore Automatic Tape Analyzer or "Crudometer" show that such a high temperature ultra-filter, now under development, will have application in these plants.

"In closing, I want to plead for utility engineers to give full consideration to high-rate filters and condensate scavengers for their high pressure plants above 1800 psig, taking into account all of the costs and advantages including the considerable simplification of makeup feedwater treatment equipment as was found at Little Gypsy Station."

Cleaning

Dr. Ulmer: *"Normal operation does not appear to be a problem with proper designs of preboiler systems. That is,*

when a proper feedwater is available. However, attention should be given to initial cleaning, storage when 'idle,' drawing procedure."

R. B. Rosene
Dowell Incorporated

"Examination of analyses of drain solvents taken at the time of removal of mill scale from a new boiler indicate that, in many cases, several thousand pounds of iron oxide may be removed. We have evidence which indicates that initial cleaning, prior to operation, makes maintenance cleaning easier and more satisfactory. It also appears reasonable to clean the preboiler cycle to prevent carrying of this debris into the boiler proper.

"During periods of normal maintenance cleaning, it is not unusual to remove 2000 pounds of iron oxide, along with 200 pounds of copper and possibly 50 pounds each of nickel or zinc. The origin of and transport of these materials into the boiler is understood. A thin uniformly deposited film of these materials is slowly built up. A single fill treatment has been highly successful in removal of this type of deposits.

"Another type of deposit is encountered which is more difficult to remove and points out the need for initial cleaning as well as frequent maintenance cleaning as preventive measures. We are now considering very hard dense localized deposits which form in high heat input zones in gently sloping tubes. A plug of magnetite is generally formed; copper may or may not be present. Metal attack in these immediate areas may be very severe; in some cases, embrittlement of the metal has been observed. We believe these growths are due to a physico-chemical reaction. Preboiler deposits and foreign debris which settle in these areas promote nucleate boiling. The accumulations promote concentration of the alkaline boiler water. Due to the steam-iron reaction and attack by caustic, rapid metal destruction occurs.

"It is needless to say that such deposits are removed only with great difficulty. Accessibility and isolation of the areas for localized treatment is one of the major difficulties. If the initial deposit build-up is prevented or removed before boiler water concentration sets in, the severe attack observed will not likely take place. This is of course our belief only. It raises the question of how often should a boiler be cleaned? Certainly initial cleaning is to be recommended in all cases; in cases where problems of localized deposition exist, cleaning should be on a more frequent schedule than where uniform deposition occurs."

In Rebuttal

Dr. Ulmer: *"The original discussion was prepared because the power industry still is plagued with boiler tube problems. Failures are far too frequent. It was thought then and we still think that frank discussion of these problems may lead to a better understanding of the problems and to their solution."*

"The discussion received to date has been most gratifying. It shows definite interest in the problem and when such interest has existed in the past, solution of the problem or at least improvement has resulted. It is expected that still further discussion will be forthcoming. Therefore, no specific closure is offered at this time. Rather a general discussion is presented.

"A considerable amount of comment involves the author's statement that the boiler owner and water treatment company are prone to question boiler design. It is understandable that both the water treating company and boiler owner would have this opinion. The fact remains that in many cases the first time the boiler manufacturer is aware of a problem is when he is informed that tube failures have occurred and the boiler water consultant questions 'circulation.' Would it not be better for the three parties to be in agreement on these matters initially? Admittedly this is a change from the past where 'boiler water treatment is not the responsibility of the boiler manufacturer.' It still should not be but that does not mean that the boiler manufacturer should not be part of it. After all every boiler the boiler manufacturer furnishes becomes in effect a laboratory. Certainly he has an excellent opportunity to establish what treatments work best and, therefore, to be in a position to make suggestions that will be helpful.

"Referring now to some of the points raised in the discussion certainly the subject of boiler circulation came in for its share of attention. This should be the case since as pressures increase there is less and less circulating head. Our design department, that is, Combustion Engineering, Inc., is confronted with this on every job. Here are some of the items that must be considered as related by P. H. Vaughan, Supervisor General Engineering."

P. H. Vaughan
Combustion Engineering, Inc.

" 'Operation on the Narrow Edge of Perdition' as described by Mr. I. B. Dick of Consolidated Edison Co., is a very realistic statement covering operation of some high pressure natural circulation boilers today. Mr. Dick observed that generously designed boilers will operate for many years without tube failures. He has further suggested that 'skimpiness' of design may be the reason why some boilers are subject to repeated furnace wall tube failures.

"Controlled circulation is the best answer we have to the above situation and, for the past ten years, C-E has recommended the use of controlled circulation for throttle pressures above 2000 psi. Many utilities, however, continue to specify natural circulation boilers while going on to higher and higher pressure levels. Faced with this continued demand for natural circulation boilers at higher pressures, boiler companies have attempted to put out a well designed unit in spite of the shrinking circulation force as steam density and water density converge at higher pressures.

"The boiler designer does not have much to work with however. At 2000 lb pressure the available head is down to 9 or 10 psi on a one million lb capacity boiler operating at six to one circulating ratio. A pound or so of this must be used for steam generation. There remains a circulating force of $8^1/_2$ psi which must overcome all entrance losses, exit losses, and friction losses of all downtakes, heated tubes and relief valves. It must assure a more or less uniform flow through the 500 or more parallel furnace wall tubes and at the same time maintain sufficient velocity to protect even the least favorable tube. The designer proceeds with his design. There are other considerations far more pressing at the moment. He must get his heat release down to prevent slagging, but he must still have sufficient furnace exit gas temperature to satisfy the requirements of superheat and reheat. Also, he must consider the requirements for completing combustion in the furnace. With the prime design requirement met, he can now go back to considering circulation.

"From a practical standpoint, heat absorption is far from uniform on furnace wall tubes. Because the furnace is rectangular, the corner tubes receive less heat. Frequently an arch extends out into the furnace cavity from the rear wall. This results in shaded areas where different absorption rates exist. Burners that will give uniform absorption to all tubes cannot be installed and because burners are installed in localized areas there will always be zones of higher heat absorption.

"Besides the variation in heat absorption, the furnace wall tube circuits are of different lengths. The rear wall may discharge directly to the drum, the front wall may continue across the top of the boiler to form the roof, and the side walls may discharge to the drum through a system of relief tubes. Faced with the unequal heat absorption and the non-uniform circuit lengths, the $8^1/_2$ lb available head is inadequate to assure much margin for differences in operation.

"There are many things that the designer has learned to watch out for, mostly by way of bitter experiences. Unequally heated circuits are isolated so that the better circuit cannot jeopardize circulation in the poorer circuit. Minimum slopes are established for exposed furnace floor tubes, arches, etc. Uniformity of heat absorption can be better assured by use of cut-off corners in furnaces. Special care is taken to assure that particular furnace tubes are not buried for extended lengths due to necessary offsets to accommodate burners. Drum internals are designed to clearly define riser and downtake circuits. Steam separators are designed with the minimum practical pressure drop in order to leave as much as possible of available head for boiler circulation. Minimum circulation ratios are established for various operating pressures. Studies are made and sufficient downtake and relief tube areas are provided to satisy these prescribed levels.

"There are other considerations in connection with heat release and burner locations which are beneficial from the standpoint of circulation. Maximum average heat releases are established at 80,000 to 140,000 Btu per square foot depending on the fuel. Localized maximum heat absorption is limited by specifying maximum heat input per burner based on the geometry of the furnace. Minimum clearances are established between burner and adjacent floor or walls. All of the above and many others are

taken into consideration in boiler design. That is, every 'practical' means is taken to insure a satisfactory operating boiler.

"However, there are always bound to be some localized conditions which cannot be forseen or completely corrected for in the design stage.

"It is necessary therefore to establish a standard for circulation which will include a tolerance to cover the variations. This company has established a circulation ratio of 6 to 1 at 2000 lb drum pressure as a guide to circulation design on natural circulation boilers.

"We believe this is adequate. We have over 50 controlled circulation boilers in operation today at drum pressures above 2000 psi. These units have been designed with an average circulating ratio of 4 to 1 in each of the furnace walls or panels. The operating record on these furnace wall tubes has been good. It has been concluded, therefore, that a 4 to 1 circulation ratio is adequate provided that each wall in the furnace can be maintained at this average. Since this cannot be maintained on natural circulation units, a 6 to 1 circulation ratio has been established as a design factor. The 50 per cent excess of circulation over the 4 to 1 circulation ratio is considered to be the tolerance."

Dr. Ulmer: *"Another item that should receive more attention is control or supervision of treatment. Professor Straub has covered that in the following."*

Prof. F. G. Straub
University of Illinois

"This discussion is very enlightening; however, there is one point which should receive more consideration. Various chemical treatments are discussed without stating who shall be responsible for the maintenance of these treatments. Many power plants have been operated at relative low steam pressures before the newer higher pressure equipment has been placed in service. The chemical control in the lower pressure plant has not been considered critical and it has often been handled by the regular operators who have conducted relatively simple chemical tests at rather irregular intervals. When the new equipment is placed in service the chemical control is often a mild modification of that previously used, and after a period of operation under these conditions water side tube failures occur. In many instances these failures are traced to inadequate chemical control.

"Most of the chemical controls for the higher pressure boilers require the use of instruments and chemical procedures which the operators do not have the time nor the knowledge to handle correctly. Once the limits of chemical control have been established they should be under the supervision of men having sufficient chemical and engineering training to comprehend the various problems encountered. These men should be at the operating level in the plant so they will be familiar with the day to day operation. Their work should involve more than the collecting and analyzing of various samples. They should be able to detect variations from the normal and able to conduct additional tests to establish the causes of the variations. These men should fit into the organization at a level where their compensation as well as authority is such as to attract and hold responsible thinkers.

"When management recognizes that the chemical control of the treatment in the larger steam power plants is a full time position requiring well trained men the largest portion of their water treatment problems will be solved. Cost of these men will be a small investment compared to the savings which will result by continuous operation without unscheduled outages caused by boiler tube failures."

CORRECTION NOTICE: *The November issue of* COMBUSTION *carried the article "Vibration Cleaning of Boiler Heating Surfaces" from Teploenergetika, July 1959. The article was translated by V. A. Ferencko Combustion Engineering, and should have been so noted. Our apologies.*

At a time when the cries for improved engineering education and application of engineering skills are most frantic we are happy to present a clear and well-considered program designed to help meet both objectives. Perhaps the most striking aspect of Commander Brooks' suggested program is that it can be accomplished within our present educational structure—without vast expenditures—and it can be accomplished now.

Improving Understanding by Guiding the Selection of Thesis Subjects*

By COMMANDER R. L. BROOKS, USN†

Introduction

TWO problems which have been much discussed in recent years are the shortage of well-qualified engineers in this country, and the weaknesses in our system of educating students for engineering and scientific fields. If we may assume that these discussions have demonstrated that there is such an engineering shortage and that the education system does have weaknesses, then it would appear that suggestions are needed which give promise of improvement for either or both of these problems.

One such suggestion is presented below. Briefly, it involves setting up of close working relationships, in order to improve the selection and execution of thesis subjects, between research activities and universities. If properly handled, such relationships could result in direct benefits of considerable importance to each research activity and to the students, while side benefits would also accrue year by year to the universities. At the same time, mutual understanding would be cultivated and a broader community of interests would grow up among the students, the professional personnel of the research activities, and those representing the universities.

Need for Improvement in Education

Launching of the first Russian satellite was quickly followed by a public outcry against the many alleged defects in our educational system. While the primary target of this emotional reaction was the secondary school and its partial failure to give our youngsters a proper background and motivation toward the sciences; critical attention has also been directed at other parts of our educational system. This attention was to some extent only a continuation of earlier discussions of the need for improvement in our schools. As one example of such discussions, in June 1956 (1), the Engineers Joint Council pointed out the need for professors to state clearly the employment conditions that students may expect as professional engineers, in order that the movement toward unionization of engineers might be counteracted. This movement was believed to result from a failure to recognize adequately the needs, responsibilities, and contributions of professional employees. The Council also emphasized that colleges must develop in engineering students an understanding of professional concepts by demonstrating the application of these concepts to the solution of actual engineering problems. A need to expand opportunities for engineering educators to become better acquainted with the total environment in which engineers must work was also stressed. For this purpose, the Council recommended temporary employment of educators in nonacademic fields, and the utilization of employers with "professional vision" in classrooms and in student seminars. Such action would enable students to appraise more realistically their status following graduation.

It has been estimated that 80 per cent of all engineers are employees rather than private practitioners, which is not the case with other professional people such as most doctors and lawyers. Engineers in their every day problems are often concerned more with getting things done by people than with working out textbook type solutions, a fact sometimes overlooked by engineering colleges.

From such ideas, one could conclude that engineering schools ought to teach their students more than is now being taught about the day to day operation of engineering organizations, and the problems of working with and through other people. Otherwise, the student may not learn during his college days how to evaluate information that can only be generated progressively or how to reason in harmony with others from incomplete data to produce necessary day to day decisions. If these concepts were carried out by more engineering schools, graduates would

* Reprinted from the *Journal of the American Society of Naval Engineers Inc.*, August 1959.

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The views expressed herein are the personal opinions of the author and are not necessarily the official views of the department of Defense or of a Military Department.

be able to enter upon their active professional careers with a better understanding of exactly what an engineer is and does.

Various steps have already been taken, principally by school authorities, to improve the students' understanding of engineering in actual practice. One such step is the cooperative plan, following the pattern of vocational schools, in which students spend fixed terms working as engineers with industrial companies. Also, many engineering professors carry out research investigations for industry in a consultant capacity. In several cases, fully developed research organizations have grown up alongside the parent educational institution.

The serious weaknesses which still exist, even though improvements have been made, caused Dr. Griswold of Yale University to state: "Unfortunately most of us get no further. . .than damning the schools and waiting for Washington to do something about them" (2).

A Suggestion for Improving the Handling of Thesis Subjects

The proposal presented here involves the following elements:

(*a*) An outline of suggested thesis subjects would be prepared about once a year by each research acitivity which desires to participate in such an endeavor.

(*b*) Such outlines would be worked up by program managers and would, for each subject, give a brief description of the work needing to be carried out, indicate its importance in a current or projected field, show its relation to key reference material, indicate equipment and calculating machines that will be needed, and give the name of the engineer at the research activity who would be available for advice and coordination.

(*c*) These outlines would be furnished to several colleges which offer degrees in appropriate fields and which desire to receive such assistance.

(*d*) Thesis supervisors at the colleges would use the latest outlines in assisting students to select a subject which most nearly satisfies the individual student's needs. Supervisors would continue to exercise direct authority in determining adequacy of the subjects chosen and quality of results achieved, in relation to the required academic standards.

(*e*) Each student would then carry out his work of thesis preparation, experimentation, and write-up.

(*f*) In order to assure that the thesis work helps to satisfy the needs of the research program from which the subject was selected, periodic reports should be submitted to the program manager, and his guidance requested. This can best be accomplished by personal visits of the student where possible.

This system would satisfy the requirement given by Captain Chadwick in reference 3, that a thesis should provide practice to the student in combining study with creative endeavor to demonstrate the natural interchange between education and design in advanced areas inhabited by outstanding teachers.

Benefits That Could Result

For each thesis that is carried out under this system, substantial benefits could be gained by the student, by the thesis adviser, and by the manager of the research program. But, probably the most important result is the improvement in understanding which should come from the closer contacts.

The student who carries out a thesis selected in this manner, gains the confidence that he is working on a subject of worthwhile value and of current importance; he gains a direct and welcome access to personalities and organizations actively engaged in research work; he gains a feeling of contributing a necessary part to the overall team effort; and he gains the chance to seek employment at this same research activity after completing his college work. Possibly his most important benefit is the opportunity to observe actual working conditions as they exist in practice, and thus be able to make a better choice when he takes a job and begins his engineering career.

Thesis advisers at the college gain a better conception of current status of developments; they gain a more direct partnership position in building for a better future; and they gain a self assurance that they are helping the flow of ideas which will break down the barriers that tend to grow up between the academic and the workaday worlds. In addition the relationship between instructors and students should improve. In reference 4, General Hershey discussed the difficulty of maintaining the propriety of these relationships in the face of the recruiting attractions being offered by industry.

Those who manage research programs can assign top priority to subjects which need resolution but are held up by a shortage of engineers. Such subjects are usually very plentiful, especially at the level of difficulty appropriate to bachelor's and masters' degrees. The research activity gains in man hours of student effort proportional to its zeal in developing such a thesis program; it gains improved understanding and public relations, and what could be most important, it gains personal contacts which should lead to the recruiting of some of the students to take jobs in its active organization. In addition after having observed the students' abilities while carrying out the thesis, the research activity will be better able to choose the best persons to fill its vacant positions.

Responsibility for producing results in each program from which subjects would be selected under such a procedure, rests with the research activity. For this reason, the initiative in developing a thesis system as proposed above should also come from the research activity. Potential benefits which could be gained seem to be a real inducements for such initiative by progressive research organizations.

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3. The Education of Naval Engineers by Captain Guy Chadwick, U. S. Navy, Retired, pages 35–48 of February 1952 *Journal of American Society of Naval Engineers.*

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ASME Annual Meeting Highlights—I

THE Chalfonte-Haddon Hall Hotel in Atlantic City was the stage for the 1959 ASME Annual Meeting which was in full swing as this issue went to press. Some 320 papers filled out the technical program and the social side of the meeting again appeared to be highly successful and enjoyable. Registration reached 3700 on Thursday with one day still to go. In our January issue we shall report on new officers along with abstracts of exceptionally interesting papers not covered in the following.

Air Pollution

"Current Status of Air Pollution Research in the United States" as reported by **Arthur C. Stern** and **Harry Heimann,** U. S. Dept. of Health, Education and Welfare, Public Health Service, is a substantial one. It is financed mainly by governmental funds, and is distributed among 11 governmental, 39 university and 18 research institute and private laboratories. The total number of independent projects is approximately 140. Some 350 full-time and 400 part-time workers are engaged in the total effort. The laboratory conducting the greatest number of projects is the Robert A. Taft Sanitary Engineering Center of the United States Public Health Service.

This air-pollution research effort reached its present activity level only within the past 3 years, the big increment occurring after the enactment in mid-1955 of the Federal Air Pollution Research and Technical Assistance Act. The major emphasis in air-pollution research in the United States is on studies which relate to the type of air pollution exemplified by Los Angeles "smog." Since many of the factors contributing to this type of air pollution are increasing in all large metropolitan areas in the United States, the results of this research it is felt will enhance the understanding of present and potential problems throughout the country. Most of the research projects deal with the role of the automobile as a smog source.

A corollary to these efforts are current research on other hydrocarbon and nitrogen-oxide sources; namely, solvent evaporation, petroleum refining and the burning of fuel oil, natural gas and several kinds of wastes. Included is intensive research on domestic, municipal and industrial-type incinerators.

A national air-sampling network to provide basic data on air quality has been established. A precipitation-sampling and analytical scheme similar to that in Europe is undergoing field trial. A comprehensive air-pollution survey of a community, similar to that conducted at Leicester, was completed earlier this year in Nashville, Tenn. The findings are currently being analyzed. This study follows earlier ones completed in Louisville, Ky., and in the Detroit, Mich., and Windsor, Ontario, area, comprehensive reports on both of which have recently been published.

There is little research under way on problems associated with the burning of coal. The principal studies are parallel investigations by a coal-trade association and a governmental laboratory of the means of SO_2 removal from flue gas. The principal industrial groups sponsoring some air-pollution research are the paper and pulp, phosphate rock and steel industries, and the automobile and petroleum industries.

Broadly, two main courses of action are being pursued simultaneously in the health studies. The first concerns morbidity and mortality statistics of communities to determine if aberrations in health patterns occur, and if they are related to air pollution. The second course is to define the biological or health effects of single and multiple known or suspected constituents of air pollution. This dichotomy covers both the epidemiological and laboratory experimental areas of study.

H. C. Austin and **W. L. Chadwick,** Southern California Edison Co., collaborated on the paper "Control of Air Pollution From Oil-Burning Power Plants." Since the previous report on control of air pollution from power plants in Southern California was made in 1957, Southern California Edison has continued its research and development work in the field with significant progress. Although most of the work concerns the combustion of fuel oil, some of the results may also apply to control of pollutants from combustion of coal and natural gas and be helpful to air-pollution control efforts in general.

In 1951, A. J. Haagen-Smit proved conclusively that the reaction between unburned hydrocarbons and nitrogen oxide in strong sunlight produced the characteristic air-pollution condition in Southern California. With this understanding of the basic chemical reaction, efforts have been made to control the release of hydrocarbons and much has been accomplished by industry toward this end.

To assist in fixing perspective, the authors stated that at the end of 1958, assuming an average of only 100 hp per engine, there were 78 times as many kilowatts operating in automobiles, trucks and buses in the Los Angeles basin as there were in all the thermal-electric power plants in the same area. These automobile kilowatts represented twice the kilowatt capacity of all thermal-electric plants in the United States.

The major role of the internal-combustion engine in forming pollutants, including both hydrocarbons and nitrogen oxides is obvious.

In 1947, a state law was passed which was intended to regulate air pollution from industry by declaring it a violation whenever any stack plume becomes "of such opacity as to obscure an observer's view to a degree equal to or greater than" smoke of Ringelmann No. 2 shade for

more than 3 min in any hr. In 1955, new power-generating stations in Los Angeles County aggregating 1 million kw in capacity were denied permits to operate because it was charged that when burning fuel oil they would on occasions violate the opacity regulation. Control regulations also set 0.2 per cent by volume of sulfur measured as SO_2, as the maximum allowable release from a stack and set not more than 0.3 grains per standard cu ft as the limit for dust loading. In typical experience, the sulfur products have been about one-half and the dust loading about 15 per cent of allowable limits. But, at times, dependent upon several variables, the Ringelmann No. 2 opacity requirement could not be met. As a result, because curtailment of the production of electric power and the resulting losses to the public were completely unacceptable, hearings and variances became necessary.

Much effort was directed toward the reduction of plume opacity—the only air-pollution control rule which the utilities were charged with violating. In spite of continuing studies, the physics of this phenomenon are still not fully understood. It is generally agreed that plume opacity is affected significantly by: (*a*) the amount and size of particulate matter present in the stack gas, (*b*) the amount of SO_3 present and (*c*) the amount of water vapor present. Opacity also depends greatly upon: (*a*) atmospheric conditions, (*b*) lighting conditions and (*c*) the background against which the plume is observed. In an elaborate study of the conditions under which plumes form, made at a coastal station, colored photographs were taken every hour from daylight to dark and for a period of two months. Wind direction and velocity, air temperature and humidity, light intensity, the amount and type of fuel being burned, the temperature of stack gases and other pertinent data were also recorded. No clear correlations could be established between the plume appearance and any of these factors.

In their conclusions the authors felt it desirable to emphasize that, although intensive effort has been applied to minimizing the particulate matter emitted from furnaces while burning fuel oil, and reducing the emission of sulfur oxides, particularly SO_3, there is no substantial evidence that either of these contaminants has been harmful or has been present in the general atmosphere in sufficient quantities to be considered a significant air pollutant. There is still controversy among authorities as to the health effects of the existing SO_2 levels.

George C. Jefferis, Philadelphia Electric Co., and **J. D. Sensenbaugh,** Combustion Engineering, Inc., discussed "Effect of Operating Variables on the Stack Emission From a Modern Power Station Boiler." In view of the importance of dust and oxides of nitrogen emissions, a series of tests was conducted in which the effect of various operating variables was determined on the dust loading, the combustible content of the dust and concentration of nitrogen oxides. These tests were carried out on the emissions from Unit No. 1 at Schuylkill Station of the Philadelphia Electric Co. This is a twin-furnace unit of 186-Mw capacity. The furnaces are tangentially fired, and the present fuel is oil, with provision for future coal-burning. The burners are of the wide-range mechanical atomizing type with a return-oil system. Steam temperatures are 1050/1000 F. The unit is designed for temperature control by burner tilt and gas recirculation, as well as spray desuperheaters for both superheater and reheater.

Closing the main dampers slightly and opening up the auxiliary dampers quickly produced large increases in dust loading and combustible content in the initial series of tests.

In the second series, a much wider range of damper settings was investigated. The dust-loading curve did not rise as sharply as under the previous conditions, and the combustible content was essentially constant over the entire range of damper settings.

In the second series, an extensive set of nitrogen-oxide determinations were made at various damper settings. Results showed a decreasing trend in NO concentration as the main dampers were closed and the auxiliary dampers opened.

Normal practice at this plant has been to operate with oil temperature in the 230–240 F range. In both series of tests, increasing the oil temperature by approximately 35 deg F halved the dust emission and reduced the combustible portion by 15–17 per cent.

This unit is equipped with tilting tangential burners. The angle of inclination of these burners can be varied through 30 deg above and below the horizontal, with the horizontal position designated as zero tilt.

With no gas recirculation, varying the burner tilt did not affect the dust loading or nitrogen oxides. With gas recirculation, the dust-loading and combustible curves had the same shape with a maximum near zero tilt. The variation in oxides of nitrogen concentration was in the opposite direction, with a minimum in the vicinity of zero tilt.

When the smaller N-12 burner tips were used, the pronounced maximum in the dust-loading curve at zero tilt appeared to be eliminated. Improved fuel atomization with the smaller tips would, of course, contribute to more complete combustion. As expected, excess air had a pronounced effect on all of the quantities studied. Variation of the oxygen percentage over the approximate range 2–4 per cent produced a dust loading at the higher end of the range that was only 20 per cent of that found at the lower end. Correspondingly, the combustible content of the dust was reduced by 17 per cent. On the other hand, increasing the oxygen percentage increased the oxides of nitrogen from 184 to 258 ppm.

Use of the smaller burner tips gave a spectacular lowering of the dust loading to 0.049 gr/SCF at 2.4 per cent O_2 compared to 0.142 gr/SCF at 2.2 per cent O_2 with the original tips. At the same time, the combustible content was reduced by 21 per cent. At the 3 per cent O_2 level, the dust loading was halved with the smaller tips. The dust loading increased with increasing gas recirculation at zero tilt. However, these tests include the effect of burner tilt as well as the effect of gas recirculation itself. Other tests at positive tilts with varying gas recirculation gave a constant dust loading. The combustible content seemed to be little affected by the quantity of recirculated gas, although there was considerable scatter in the results with positive tilts. The concentration of nitrogen oxides tended to decrease with increasing gas recirculation.

Two tests on the effect of soot blowers were run under normal operating conditions. In one test, a dust-loading determination was made over a complete soot-

blowing cycle. This was compared with a control test with no sootblowing. The dust concentration entering the mechanical collector was approximately twice as high during sootblowing.

Pumps

The effect of transient suction pressure decay on a centrifugal boiler feed pump has been under study by Karassik, et al. Using concepts established by these authors **Rodney S. Thurston,** Cornell University, in his paper "Design of Suction Piping and Deaerator Storage Capacity to Protect Feed Pumps" presents an analytical method for determining the minimum permissible weight of water ratio between the deaerator storage tank and the suction piping to the boiler feed pump. With sufficient capacity this tank is capable of insuring against flashing at the pump's suction, thereby avoiding cavitation and vapor binding of the pump.

Mr. Thurston advocated the following steps in establishing deaerator storage capacity:

(1) Select the expected maximum feedwater flow and determine the required NPSH at that flow.

(2) Select the minimum condensate enthalpy expected during the residence time. This will probably be that of the second downstream heater in the event that the first downstream heater is out of service.

(3) Determine the value of the deaerator enthalpy h_2 at the end of the residence time from the relation between p_2, p_0, the required NPSH, the static head and the friction drop.

(4) Solve for the minimum ratio between the storage capacity and the capacity of the suction piping. Actual storage must be larger than that indicated here.

(5) If it is impractical to use as large a storage capacity as indicated or to reduce the suction piping any further, investigate whether an increase in static head is practical.

Edwin L. Pace, General Electric Co., selected "Integration of Turbine-Driven Boiler Feed pumps in Large Power Plants" for his topic. In the past 5 years, there has been a great revival of interest in steam turbines for driving boiler feed pumps in large central stations. This is primarily because of the rapid increase in pumping power, due to higher steam pressures and kilowatt ratings of the plant. Recently developed high-speed pumps, with lower cost and shorter shaft span, are attractive when directly connected to steam turbines in these high pump power ranges. The almost universal acceptance of the reheat cycle offers opportunities for gains in net heat rate by use of noncondensing extraction turbine drives for auxiliaries. Tandem-compound main turbines are now frequently used at high ratings, with attendant high exhaust loss, which makes possible gains in heat rate by use of condensing-turbine auxiliary drives.

For generating units of capacity greater than about 150,000 kw, it is usually possible, with noncondensing extraction turbine drive of the boiler feed pump, to show improvements in net heat rate at rated load of 5 to 25 Btu/kwhr as compared to motor-driven pumps. Between rated load and half load, the average improvement is often greater than at rated load. Below half load, where both the amount of fuel burned per hour and the expected hours of operation are lower, the heat rate generally is higher than with motor drive.

With the pump driven by a condensing turbine, somewhat greater improvements may be obtained, if exhaust loss of the main turbine is high.

Throttle steam for the feed-pump turbine is normally taken from the cold reheat line and the steam extracted and exhausted from this turbine is used for feedwater heating. Heaters connected to the feed-pump turbine are located in succession below the heater at the cold reheat line. Separate first stage nozzles and governing valve admit steam directly from the boiler for light load, starting, and certain emergency conditions. This arrangement generally results in an improvement in heat rate at rated load of 5–25 Btu/kwhr as compared to a similar station with motor-driven pumps. The reason for this is that part of the feedwater heating is done by steam at a lower temperature than could be extracted from the reheat turbine at the same pressure.

The author then covered the disposition of exhaust steam, the distribution of feedwater enthalpy rises among heaters, number of extractions, pump speed, pump size, location and some material on operation.

R. G. Jobe, Shell Chemical Corp., gave a paper on "Pump Standardization. . .A User's Concept." Since the centrifugal pump is one of the widely used items of equipment in the chemical industry, considerable incentive exists for standardizing this equipment and, in fact, an industry-wide standardization program is in progress. In considering the adoption of a standard pump for his plant, the author made a plant-wide study covering approximately 650 centrifugal-pump installations to determine the range of head and capacity requirements, and to obtain cost data to serve as the basis for selecting the optimum standard design.

To establish the range of head and capacity required, the design points for all existing pumps were plotted on one head-capacity curve for comparison. Analysis of the distribution of these points led to the conclusion that the standard pump should be capable of developing a shut-off head of at least 200 ft and a differential head of 120 ft at a capacity of 250 gpm. A pump meeting these requirements would handle approximately 80 per cent of the plant centrifugal-pump applications.

The basic economic consideration was the lowest overall cost for the life of the pump, one which would provide an economic balance between the first cost of purchase and installation and the continuing cost of operation and maintenance.

Comparison of continuing costs with capital cost showed that, on the average, during the life of the pump the sum of the continuing costs (maintenance, power, oil) would exceed the capital cost by several hundred per cent. This indicated that the standard design should emphasize reduction of the continuing costs. This does not mean that capital costs were to be disregarded, but rather that maintenance cost-reduction features would be favored where compromises would be required.

Further analysis showed that maintenance costs were among the most important factors contributing to the continuing costs. It was apparent that maintenance-cost reduction should be one of the primary objectives.

Further study led the author's company to conclude that (*a*) the standard pump should be designed so that it could be quickly removed from service for shop repairs; that (*b*) the pump should be simple to dismantle and reassemble in the shop; and that (*c*) the pump should be designed to use a minimum number of component parts.

Evaluation of the overall economics and performance requirements resulted in establishing the following criteria: (1) The pump should be capable of providing sufficient capacity to meet the performance requirements for at least 80 per cent of the centrifugal pumps in the plant. (2) It must feature maximum dimensional interchangeability both in mounting dimensions and pump parts. (3) It must be simple to remove and install. (4) It should use a minimum number of parts. (5) It must be simple to dismantle and repair under shop conditions. (6) The installed cost should be as low as possible, consistent with maintenance requirements and reliability.

Although the new design has only recently emerged from the development stage, some indications as to the effect of the design on plant pump costs have resulted from field experience. Comparison of the installed costs for the eleven test units with similar costs for conventional medium duty horizontal centrifugal pumps in these services shows that installed costs (including the price of the pump) were reduced 20 per cent to 35 per cent below that of conventional pumps of cast-steel construction. These savings are due largely to the elimination of concrete foundations and the elimination of the shaft coupling with its alignment problems.

C. P. Kittredge, Princeton University, covered the subject of "Centrifugal Pumps Used as Hydraulic Turbines." Centrifugal pumps may be used to advantage as hydraulic turbines in applications where the required power is rather small and low initial cost is more important than high efficiency. An estimate of the performance of a centrifugal pump when used as a turbine can be made from published curves of complete characteristics for typical pumps. The purpose of this paper is to present some of the available data on pumps and to show how to select a pump which will meet specified requirements when used as a turbine.

The performance of a given pump when used as a turbine, in the author's opinion, can be estimated by the methods described. However, it probably will be necessary to apply the affinity laws over such wide ranges of the variables that the usual degree of accuracy should not be expected. Also, considerable care should be exercised if it becomes necessary to interpolate.

It should be possible to select the correct size from a series of pumps to fulfill given turbine requirements even though the computed performance may differ from the results of subsequent tests.

Fuels and Firing

The problem of protecting industrial boilers from explosions and maintaining high reliability of the units is not easily accomplished at the present time. Furthermore, it is difficult to get a group of power engineers to agree as to what constitutes a safe boiler free from potential furnace explosions. For several years the Fuels Div. has tried to stimulate discussions to gain a basic agreement. **M. L. Jones,** E. I. du Pont de Nemours and Co., in his paper "Protecting Industrial Furnaces From Explosions" made no attempt to give all of the answers to this problem. However, his primary objective was to present some of the problems for discussion and thought that at some future data a realistic and practical solution to the problem might be achieved. The discussion is limited to liquid or gaseous fuel-fired boilers with a maximum size of 100,000 lb per hr. The size range includes the shop-assembled units which have become popular in industrial plants in the past few years. Various phases of the problem include the following categories: (1) causes of furnace explosions; (2) humans versus instruments; (3) safety-type equipment—(*a*) flame failure, (*b*) equipment failure; (4) reliability of equipment.

From records available to the author, the major number of furnace explosions occur during light-off or relighting. These are due to inadequate equipment, manpower failure, improper application of equipment, safety equipment bypassed and malfunctioning of safety equipment.

Other furnace explosions have occurred during operation due to momentary fuel failure, improper fuel-air ratio control, rapid load changes and power failure.

In the October 1956 issue of *The Locomotive* of The Hartford Steam Boiler Inspection and Insurance Co., Table I shows the cause of failure classification for furnace explosions. From this it can be seen that failure to test and maintain control devices, and failure to ignite properly account for the majority of the accidents in suspended fuel-burning units. This can indicate that the human being is not capable of servicing the equipment being furnished.

To reduce accidents due to furnace explosions, the engineer must first establish several basic policies, which in many cases require management approval. The most important of these is a decision whether a well-trained and reliable operator is better insurance than a complex installation of instruments. In many states and cities, existing laws require that a licensed operator be in attendance of a boiler installation. Thus, the operator must be on the payroll so a high degree of instrumentation will mean the operator has few duties to perform.

In those areas where a licensed operator is not required, a sometimes oversold, highly instrumentized boiler frequently results in a management decision that no operator is required or that the unit can be maintained by anyone regardless of qualification. This can create serious complications as such an operator is unable to interpret any malfunction of equipment and thus cannot take preventive steps to correct for abnormal situations.

Before the problem is solved, both manufacturers and users must reach some basic decisions, such as: (1) To what degree is automatic control essential? (2) What function failures in a system require shutdown of the unit for protection? (3) How can the components protecting the system be readily checked?

After such decisions are established, standardization of protective components of the system must be established so that both manufacturer and user can be satisfied that the system will provide the necessary protection and can be maintained readily. To accomplish this, it is recommended that the ASME assume the

leadership by preparing and issuing a code or standard that will provide a safe and reliable system for protecting industrial furnaces from explosions.

"The Direct Method of Testing Heating and Power Boilers" by **E. P. Carman,** Fuels Consulting and Testing Associates, presents the advantages and requirements for direct input-output testing of heating and power boilers. Reasons why the Bureau of Mines and the author's organization prefer this method wherever it can be used are given, along with the methods used, and essential, for calibrating instruments and test equipment.

This information includes test procedures and calibrations for testing boilers of up to 150,000 lb-per-hr capacity by the direct input-output method, along with suggested means of using this test method on even larger boilers. Test results accurate to within a small faction of a per cent of specified thermal efficiency can be attained the author asserts. Further he felt the benefits in more precise knowledge of newly installed equipment may be applied over the entire life of the equipment, and by themselves indicate the desirability of this method of test, whether or not purchase specifications indicate its desirability.

One of the main problems facing the designer of a solid-fuel system for a pressure-fired device is how to introduce the pulverized or granulated particles into the combustion space against the system pressure. By far, the most convenient method of achieving this is to employ a solid-fuel pump designed to do much the same duty as a liquid pump. The prime need is to pressurize the fuel particles, or more accurately to pressurize the air, if it is a fuel-air mixture, or the water in case of a slurry, in which they are entrained.

M. N. Aref, Foster Wheeler Corp., in his paper "Pressurization of Granular Solid Fuels" reviewed the different methods of pressurizing powdered solid fuels which have been developed including proposals as well as those in operation. The work so far has been devoted particularly to a study of the characteristics of these pressurizers, in relation to their common problems of: (*a*) power loss due to venting the pressurizing air, (*b*) wear of the surfaces in contact with the solids and (*c*) effective sealing. The most practical methods have been compared on power loss, rather than power required in their cycles. It has been found that power loss due to air venting cannot be totally eliminated and that the simple lock hopper is, so far, the best available device which has the lower capital cost, maintenance requirements, power loss and better reliability. Where space is of major importance, however, the lock hopper with a moving wall can be considered as an alternative, though, it may suffer from an increased wear rate and a reduced volumetric efficiency.

Until recent years, no such pressurizer had been required and as Mr. Aref reported, very little work had been done on the pumping of solids. The advent of the newly developed coal-burning processes in combustion and gasification at elevated pressures provided a stimulus to research in that direction. Among these processes were the coal-fired gas turbine, pressure-fired boiler for the steam-gas cycle, and pressure gasification. In these processes, the solid-fuel may be pulverized, crushed or sized in the case of coal; or sized in the case of other materials. Loose-packed bulk densities may range from 20 lb/cf for sized coke, through 30 for pulverized coal, 40 for sized coal, 55 for crushed coal, 100 for stone, up to 200 for rich ores. Capacity may vary from 2 tons/hr for a small gas-turbine plant to 100 tons/hr or even higher for a big gasification plant. In the latter case, though, multiple units may be used to reduce spares, so throughputs of 2 to 25 tons/hr cover the likely unit range. Delivery pressures may range from 5 to 20 atm and the powdered fuel size, for satisfactory pumping, may vary from 80 per cent through 200 mesh for pulverized down to 0–$^1/_8$ in. or 0–$^1/_4$ in. for crushed.

W. H. Rowand and **E. G. Kispert,** the Babcock and Wilcox Co., combined talents in the paper "Recent Boiler Design Practice." As the authors mentioned high costs combined with increasing demand for electrical power have tended to make stand-by equipment economically impractical. Therefore, plants capable of operating with high availability, low maintenance and high efficiency over the life of the equipment have become mandatory. Super clean stacks and the extension of remote, centralized operation are becoming increasingly important to the power industry.

This paper indicated something of what Babcock & Wilcox Co., as one steam generator manufacturer, is doing in an effort to further these ends. A similar paper was presented in 1947.

Corrosion

Several years ago inspection of the reheater and finishing superheater tubes in a 1055 F 1005 F boiler firing pulverized midwest coal revealed considerable external corrosion loss of tube metal. Although in operation only two years, some 321 stainless-steel reheater tubes had lost about 50 per cent of the original 0.125 in. thickness, a penetration rate of 0.032 in. per year. Corrosion was spread fairly evenly from left to right and top to bottom in both reheater and finishing superheater. This information initiated inspection of 26 pulverized coal-fired boilers in various parts of the country to determine the nature and extent of the corrosion problem. Advanced corrosion was observed in only a few units.

These findings led to the establishment of a research program to determine the cause and prevention of accelerated wastage. The corrosion mechanism has been studied extensively and a description of these investigations constitutes the main body of the paper, "Corrosion of Superheaters and Reheaters of Pulverized-Coal-Fired Boilers" by **Wharton Nelson** and **Carl Cain, Jr.,** Combustion Engineering, Inc.

Initial laboratory experiments sought to find the corrosion rates of T22 and 321 stainless-steel alloys in flue gas and air. These tests indicated: (1) Flue-gas attack on T22 mounted rapidly with increasing temperature above the normal limit of use, 1100 F. (2) Gas-phase corrosion of T22, which developed a semi-protective scale, followed the parabolic law. (3) The T22 scale spalled off upon reaching a critical thickness. This characteristic

may account for much of its wastage in soot-blower impingement areas. By contrast, the 321 stainless steel in flue gas rapidly built up a type of scale which was fully protective and nonspalling. (4) Flue-gas attack on 321 stainless steel, even at temperatures as high as 1400 F, did not result in the corrosion rates observed in actual boiler operation at the first unit inspected.

Other tests using pure sulfur dioxide and pure sulfur trioxide with T22 and 321 stainless steel at 1200 F showed that neither atmosphere was substantially more corrosive than synthetic flue gas. It was concluded that gas-phase attack, particularly of stainless steel, could not account for the corrosion rates observed in operating boilers, and that an inherently faster liquid-phase corrosion mechanism was probably involved.

Although present studies are not far enough along to solve the liquid-phase corrosion difficulties, a number of approaches do offer promise for its amelioration. Use of more corrosion-resistant alloys would seem the easiest approach. No practical alloy has yet been found, however, which offers consistently better resistance than 321 stainless steel in this service, although many have been tested in field exposure as welded-in tube sections. Corrosion-resistant coatings have not looked promising due to cost and to the fact that they are effective only as long as unperforated. The search for better alloys and coatings has by no means been exhausted by present work and would seem a rewarding field for future effort. Operating conditions such as fineness of coal were found to have a decided bearing on corrosion rate of stainless steel. Use of coal ground to 80 per cent through 200 mesh rather than the normal 65 to 68 per cent at Joppa indicated lower metal loss in the 950 to 1250-F metal-temperature range. No doubt the use of better quality coal would ameliorate corrosion trouble. Unfortunately, present knowledge does not allow setting adequate limits on the following coal qualities: Low sodium, sulfur, potassium and ash content, and high ash-fusion temperatures.

A field method which has proved very effective for reducing lead-tube corrosion has been the application of stainless-steel shields on the front (windward) 180-deg surface of lead tubes in the deposit-forming areas of finishing super-heaters and reheaters.

The present work the authors state has shown that molten complex iron and/or aluminum alkali sulfates formed in fireside deposits of boilers having steam temperatures above about 950 F are responsible for corrosion of superheater and reheater tubes. This corrosion is a chemical reaction in which tube metal reacts with molten sulfates to give iron oxide and sulfide. It starts at temperatures below the oxidation (scaling) temperature limit for alloys used in these sections of a boiler. Studies to find more corrosion-resistant alloys or less corrosion-producing coals seem promising fields for future effort.

P. Sedor, E. K. Diehl and **D. H. Barnhart,** Babcock & Wilcox Co., joined forces to report on "External Corrosion of Superheaters in Boilers Firing High-Alkali Coals." This paper describes the nature and occurrence of corrosion observed on superheaters at Will County and Ridgeland Stations of the Commonwealth Edison Co., Chicago. The paper further presents some of the results obtained from an experimental study of the factors involved, and outlines the control measures applied to prevent further serious loss of tube metal.

Owing to the arrangement of surface, the temperatures of the tubes in the long platens are low, while those of the tubes in the short platens are comparatively high. The maximum metal temperature occurs at the bottom of the short platens in the front of the furnace and has been measured as high as 1225 F, although it is usually around 1175 F. The true gas-temperature range in this zone is 2100 to 2300 F with the boiler operating at rated capacity.

Metallographic examination of the tubes indicated that the corrosion at the Ridgeland and Will County Stations was the pitting type, accompanied by surface carburization and subsurface sulfide formation. The evidence indicates that alternate reducing and oxidizing conditions prevailed on the surfaces of the tubes with a possibility that some, but not all, of the corroded surfaces had been operating between 1250 and 1300 F.

During the 18-month period prior to the platen-tube failure, several coals from Central Illinois were burned at Ridgeland Station, of which more than 75 per cent were from Christian County mines. The analysis of the "average" coal shows it is a high-volatile, high-ash coal having a low-fusing-temperature ash. Perhaps more important to the ash-fouling and corrosion problems, it contains substantial quantities of alkalis and chorides. When these high-alkali coals are burned in boilers, they invariably result in alkali-rich and sulfur-rich ash deposits on the convection surfaces. These deposits may also lead to corrosion if the tube metal and gas temperatures are high enough.

Owing to the seriousness of the corrosion problem, several corrective measures were applied to the Ridgeland and Will Country boilers at the same time. The effectiveness of these changes is best typified by Boiler No. 5 at Ridgeland Station where corrosion had definitely been a problem and where progress was made in reducing its severity. The abrupt reduction in corrosion is likely due to the reduced metal and gas temperatures in the platens resulting from the installation of additional furnace-screen surface. Also, the use of higher excess air, from 8 per cent before up to 13 per cent now, and the installation of 25-20 clad tubes have undoubtedly been beneficial in reducing corrosion. The use of additive and the shift of soot blowers seem to have been helpful, but the role they played was not decisive in the overall effort.

The reduction in the amount of corrosion is only part of the story; there has also been a drastic reduction in the area in which corrosion occurs. In comparing this to the original area of corrosion it appears that the extent of corrosion has been reduced approximately 90 per cent. From this, it would appear that corrosion can be kept under control at a reasonable cost on these units by pad welding the wasted areas every three or four years. Even so, the problem cannot be considered solved until corrosion is arrested and, equally important, the corrosion agents identified and the mechanism completely understood. Since this is a comparatively new problem, a great deal of work must be done to reach these goals. If metal temperatures are pushed much beyond present levels, and this seems likely, the corrosion of high-temperature surfaces may become more prevalent in coal-fired boilers.

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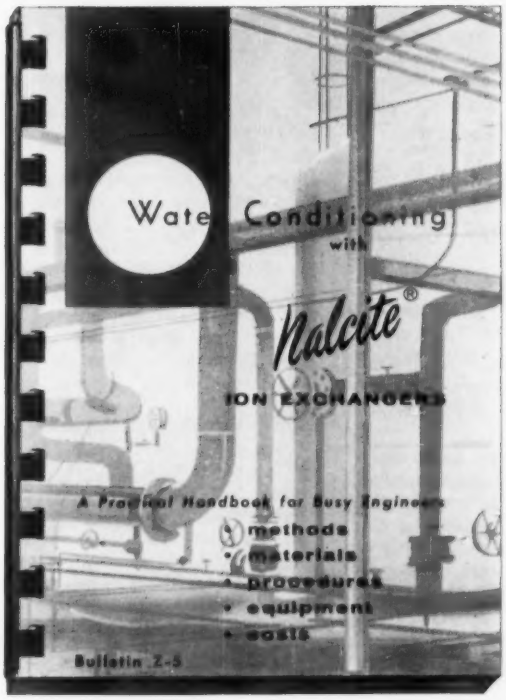

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Abstracts From the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion, Ltd., London, W. C. 1)

Power Generation and Power Plant

American Power Conference in Review. II. Anon. *Combustion* 1959, (June) 45–52.

The second part presents abstracts of papers on: 1. Once-through boilers; 2. Operation and controls; 3. Water conditioning; 4. Turbine Generators; 5. Operating Experiences.

Supercritical Pressures and Efficiencies of Steam Power Plants. P. Profos. *Sulzer Tech. Rev.* 1958, **40,** No. 4, 11–18.

Detailed calculations have been carried out by a boiler manufacturer in conjunction with a turbogenerator manufacturer to obtain data for the most efficient production of electric power from a set of assumed though realistic conditions. These were: size of unit 250 MW, coal properties net C.V. 5,550 kcal/kg, 8 per cent moisture and 25% ash, cooling water temperature 27 C. Three variants of steam parameters were considered: 1. 176 atü, 565 C (no reheat); 2. 306 atü, 600/565 C (single reheat); 3. 306 atü, 600/565/565 C (double reheat). The boiler efficiency for all 3 variants was assumed to be the same, 92 per cent at economical and 91.5 per cent at m.c.r. For these 3 variants the effective plant efficiencies increased from 39.38 to 40.49 and 41.11 at economic rating and from 38.95 to 40.05 and 40.68 per cent at m.c.r. The proposed layout for these variants are indicated.

Power Plants in the Paper Industry. H. R. Emery. *Coal Utilization* 1959, **13** (June) 22–4.

Present and probable future power requirements of the American paper industry are considered. Schemes for improving the efficiency and dependability of power generation are discussed.

Gas Turbines Progress Report. Various authors. *J. Engng. for Power* 1959, **81,** No. 3, 215–359.

The report contains the following contributions: 1. Introduction by R. T. Sawyer; 2. Materials by A. W. Herbenar and G. R. Heckman; 3. Turbine Cooling by J. B. Esgar; 4. Fuels by A. D. Foster; 5. Cycle Components by P. F. Martinuzzi; 6. Compound Piston-and-Turbine Engines by A. L. London; 7. Aviation by O. E. Lancaster; 8. Rocket Turbines by O. E. Lancaster and C. J. Bates; 8. Automotive by F. L. Schwartz; 10. Railroad by P. R. Broadley, W. M. Meyer, D. S. Neuhart, E. L. Barlow, R. C. Bond, D. S. D. Williams and B. W. C. Cooke; 11. Marine by J. W. Sawyer and H. M. Simpson; 12. Industrial and Central Station by B. G. A. Skrotzki; 13. Nuclear by R. P. Godwin and E. S. Dennison.

First Once-through Boiler. J. B. Moore. *Elect. West* 1959, **122** (May) 65–7.

The boiler for the third unit at South California Edison's Huntington Beach power station will be of the once-through universal pressure type. The 210 MW cross compound, axial flow turbine-generator unit will have operating conditions of 2,400 psig and 1,050/1,000 F reheat. The advantages and disadvantages of the boiler are enumerated and the new control system employed is described.

From C.E.G.B. Digest 1959, **11** (June 20) 1498.

New Equipment—Same Fuel. T. S. Spicer. *Coal Utilization* 1959, **13** (June) 18–21.

Spaulding Fibre Co. recently increased their steam output by the installation of two 40,000 lb/hr units producing steam at 130 psi saturated. The boilers are equipped with vibrating grate stoker, the vibration lasting 1–10 sec every two minutes, the movement being $^{3}/_{32}$ in. and the speed 600/min. The CO_2 content of the flue gas is 14–16 per cent even at low loads and the thermal efficiency 80 per cent. Fly ash arrestors have proved unnecessary when firing a coal sized 2 × $^{3}/_{4}$ in. plus 15 per cent minus $^{3}/_{4}$ in. Overfire air is about 10 per cent of the total combustion air.

Trawsfynydd Nuclear Power Station. Anon. *Electr. Rev.* 1959, **164** (June 19) 1148.

Atomic Power Constructions Ltd. have been given the order for this nuclear power station which will be erected at the northern shore of the Trawsfynydd Lake, Merionethshire. The two reactors are of the gas-cooled, graphite moderated type; by increasing the gas pressure to 240 psi a considerable reduction in the internal diameter of the pressure vessel has been made possible. There are 3720 fuel channels on a $7^{3}/_{4}$ in square pitch. Each reactor is combined with six boilers generating steam at 927 psi and 715 F and at 290 psi and 685 F. There will be four 175 MW turbogenerators.

Fabrication and Construction of Piping System for the Dresden Nuclear Power Station. G. B. Grable and A. M. Croswell. *Weld. J.* 1959, **38** (July) 657–64.

The materials, mainly stainless steels, are specified; the fabrication methods (hot forming and rerolling after welding, casting, machining and heat treatment of fittings, welding procedures) are described in detail.

Materials and Manufacturing Processes

Summary of the Work of the Committee for the Study of Creep in Metals at Elevated Temperatures. O. L. Bihet. *Bull. Trim. Centre Belge d'Étude et Doc. des Eaux 1959 II*, No. 44, 66–71 (in French).

This Committee has been given the task of determining the limits to which the steels at present on the market can be used, and to develop new alloys. A summary is given of the work of the Committee over the last few years on ferritic steels for pipework, turbine bolts, disks and superheaters, also the welding of this type of steel. Research on austenitic steels at between 600 and 700 C and improvement in behavior when hot is reported, and directives for the continuation of research are presented.

From C.E.G.B. Digest 1959, **11** (July 4) 1630.

Materials for Boiler and Superheater Tubes and Steam Pipe Lines. F. Bruhl. *Tech. Mitt.* 1959, **52** (May) 170–5 (in German).

The development of steels for pressures of up to 4500 psi and temperatures of 1200 F is reviewed and the results of long-term tests reproduced and discussed. Special attention is paid to the weldability of these steels and to joints between ferritic and austenitic steels.

The Lining of a Steel Pressure Vessel with Titanium. F. F. Ates. *Soudage* 1959, **13** (May/June) 231–7 (in French).

The technique employed for lining a vessel of 80 m diam and 4 m length with titanium of 0.8 mm thickness are described. The reasons for the occurrence of cracks are discussed.

Mechanical and Technical Properties of Beryllium. H. R. Meininghaus.

Atomkernenergie 1959, 4 (June) 231–2 (in German).

Recent knowledge of the properties of beryllium is reviewed.

Instruments and Controls

Dynamics of Superheater Control. P. Profos. *Sulzer Tech. Rev.* 1958, **40,** No. 4, 19–30. (See also COMBUSTION, 1959, **30,** October, p. 34.)

A mathematical study of the problem is presented.

Load Dependent Control of a Power Station Unit with Benson Boiler. K. Halle. *Tech. Mitt.* 1959, **52** (May) 181–9 (in German).

Control problems of power stations equipped with boiler-turbine units are discussed in general and those with Benson boilers in particular. The control system developed by Siemens-Schuckertwerke for the control of the latter under various conditions are described in detail.

Superheater and Reheater Control. H. Lobscheid. *Tech. Mitt.* 1959, **52** (May) 195–200 (in German).

Means of keeping the temperature of the superheated and reheated steam constant of a wide range of load are discussed. Coupling of the control of both on the steam or on the flue gas side and the combination introduced by Sulzer (Triflux) are described in some detail.

Railroad Car-Dumper Coal Sampling. W. R. Reichenstein and A. Bur. *Mining Engng.* 1959, **11** (May) 506–8.

The problem of obtaining a representative sample from a wagon of coal is discussed and an automatic installation described with which previous difficulties have been overcome.

Automatic Signalling Apparatus for the Indication of the Exhaustion of Cation and Anion Filters of Water Demineralization Plants. K. G. Zaydel. *Teploenergetika* 1959, (July) 14–8 (in Russian).

The apparatus is described and results of tests presented.

Nuclear Energy

4th Annual Nuclear Power Report. C. Hochgesang, R. Balent, A. R. Jones, B. L. Lloyd, J. L. Schanz, D. H. Imhoff and R. W. Klecker. *Electr. Wrld.* 1959, **151** (June 22) 63–82.

The contents of this report are: 1. Organic cooled reactor design can produce power cheaply; 2. 330e MW P W R plant operation likely in 1965; 3. B W R's economy, potential spur development; 4. Nuclear superheater augurs new era; 5. Reactor studies bring definition; 6. Nuclear power plant tabulation.

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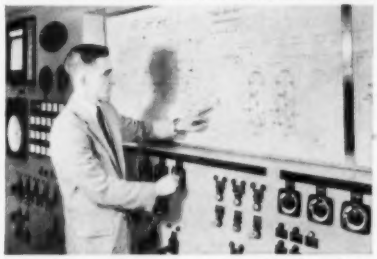

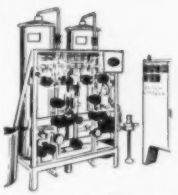

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Nuclear Energy for Process and Space Heat in the United States. P. L. Geiringer and M. J. Goodfriend. *Pwr. Engng.* 1959, **63** (June) 56–7.

Some of the essential details of the authors' report NYO-2332 are reproduced, in which the competitive threshold was studied above which conventional boiler plants would be more costly than heat generated by reactors.

Nuclear Energy Developments in Asia. J. Burkett. *Nucl. Energy Engr.* 1959, **13** (July) 365–7.

Developments in India, Pakistan, China and Japan are briefly outlined.

Thermonuclear Fusion Research for Power. L. J. Linde. *Pwr. Engng.* 1959, **63** (June) 52–5.

An outline of the American research program and the apparatus to be used is given.

Fuel Cycle Optimization in Power Station Design. P. J. Grant. *Nucl. Pwr.* 1959, **4** (July) 73–6.

A method for calculating the design of a reactor to arrive at the lowest total cost of electric power production is described.

The Economic Design of the Secondary Heating Circuit in Nuclear Power Plants. H. Steckler. *Energietechnik* 1959, **9** (July) 291–9 (in German).

Design possibilities of the secondary heat cycle are discussed and calculations made of the efficiencies of a cycle operating with saturated steam and one with superheater steam. It is shown that superheating has a considerably greater effect on thermal efficiency in nuclear than in conventional power stations.

Nucleate Boiling Characteristics of Organic Reactor Coolants. D. P. Jordan and G. Leppert. *Nucl. Sci. Engng.* 1959, **5** (June) 349–59.

The results of an experimental investigation are reported.

Burst Slug Detection in Water-cooled Reactors. D. D. Aliaga-Kelly. *Nucl. Pwr.* 1959, **4** (July) 77–9.

Six methods are described: 1. Pressure drop; 2. Tracers; 3. Direct Monitoring; 4. Delayed neutron detection; 5. Ion-exchange column; 6. Precipitation. The advantages of this last method over the others are outlined.

A High Temperature Plant of 125 Electrical MW. R. F. Benenati. *Pwr. Appar. and Systems* 1959, No. 40 (Feb.) 1329–34.

The paper presents the results of a design and feasibility study of a pebble-bed reactor (PBR) steam-power plant of 125 MW output. The reactor plant is described, fuel handling and costs discussed and the

reactor characteristics of the final design tabulated. (Text of A.I.E.E. Paper, No. 58-1110, Sept. 29–Oct. 1 1958.)

From C. E. G. B. Digest 1959, **11** (June 20) 1532.

Nuclear Energy Propulsion Plant with Gas-cooled Reactor for a Tanker with 10,000 WPS. K. Illies. *Atomkernenergie* 1959, **4** (June) 213–8 (in German).

An overall description of the study for the ship propulsion plant containing a gas-cooled reactor and a single-cycle gas turbine with electric transmission is presented. The study was undertaken at the Technical University Hanover with a grant-in-aid by the Federal Government.

The Design of the Gas Circuit of a 10,000 WPS Nuclear Energy Gas Turbine Ship Propulsion Plant. J. Busch. *Atomkernenergie* 1959, **4** (June) 218–22 (in German).

The reasons for selecting nitrogen as driving medium are discussed but owing to recent reduction in price helium has since become a serious competitor. The gas will be heated in the reactor to 650 C at 31 atm, and cooled to 40 C at 11.5 atm. The control of the propeller speed is obtained by a bypass around the low-pressure gas turbine. The layout of the circuit and design of the turbine and compressor are described.

The Reactor, Its Design and Control. W. Hubschmann. *Atomkernenergie* 1959, **4** (June) 226–30 (in German).

UO_2 is used for the fuel elements as it is at present the only one applicable at temperatures of 650 C and beryllium as canning material. Beryllium oxide has been chosen as material for the moderator and reflector because this results in the smallest reactor dimensions. Control of the reactor is by control rods (boron or cadmium) and absorbing gas BF_3 tubes; for emergencies 6 safety rods are to be provided. The reactor design is outlined.

Installations for the Emergency Cooling of the Reactor. H. R. Meinghaus. *Atomkernenergie* 1959, **4** (June) 232–4 (in German).

The necessity for an emergency cooling system is discussed and its design described. This also employs nitrogen at 20 atm cooled by sweet water which in turn is cooled by sea water.

Installation of a Nuclear Energy Gas Turbine Plant in a Tanker. K. Gerold. *Atomkernenergie* 1959, **4** (June) 235–8 (in German).

The whole plant including the reactor, gas turbine, generators and auxiliaries are placed in a safety tank of spherical shape to protect the ship and its crew. The tank is to be installed in the stern of the ship. The difficulties arising from the necessity of lifting off the top of the reactor for refueling and their influence on the design of the tank and its installation are discussed.

Material Selection for Gas-cooled Ship Reactors. W. Junkermann. *Atomkernenergie* 1959, **4** (June) 238–41 (in German).

The considerations which led to the selection of materials for the various parts of the propulsion plant are presented. Tables provide data for various materials suitable as a moderator and other materials required for structural purposes.

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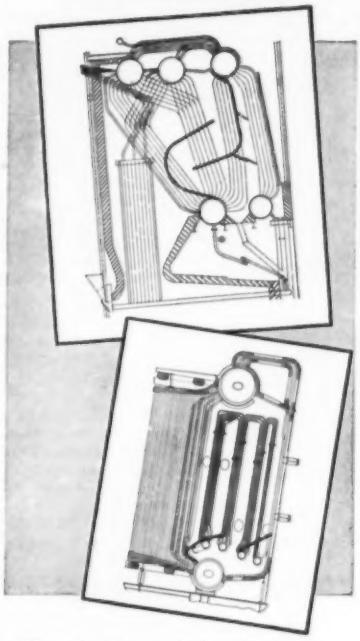

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Analysis and Testing, Research

Stress Theory of Impact Comminution. H. Rumpf. *Chem. Ing. Techn.* 1959, **31** (May) 323–37 (in German).

A detailed analysis is presented of the processes occurring during comminution by impact, the energy applied and utilized, the stresses set up in the particles and their breakage; the factors influencing the breakage (free path, air friction, particle size) and the application of the design of machines for comminution by impact.

Densities of Coals and Cokes. Anon. *Coal Research in C.S.I.R.O.* 1959, *No. 6* (Mar.) 11.

An apparatus is described which has been developed for determining the true density of porous solids by the displacement method using helium.

Laboratory Methods for Determining Corrosion Rates under Heat Flux Conditions. A. O. Fisher and F. L. Whitney. *Corrosion* 1959, **15** (May) 53–7.

Three laboratory techniques have been developed for testing the effect of heat flux and skin temperature on corrosion rates of stainless steel and cast iron in various environments and the advantages and disadvantages of each are discussed. Skin temperature was found to be the controlling factor. The practical application of the test results to prediction of corrosion rates of heat transfer apparatus in corrosive atmospheres is outlined.

Contribution to the Analysis of Fuel Ash. Chelatometric Determination of Iron and Aluminum. W. Radmacher and W. Schmitz. *BrennstChemie* 1959, **40** (May) 161–4 (in German).

Iron and aluminum can, under certain conditions, be determined chelatometrically side by side. The procedure is described in detail.

Phosphorus in Coal Ash. Anon. *Coal Research in C.S.I.R.O.* 1959, *No. 6* (Mar.) 14.

A new method for the analysis of phosphorus in coal ash using hydrochloric and sulfuric instead of hydrofluoric and nitric acid is described. Only with samples of very low phosphorus content was there an appreciable difference between the new and the British standard method.

The Viscosity of Synthetic Slags as a Function of Their Composition and Temperature. E. E. Hofmann. *Stahl und Eisen* 1959, **79** (June 11) 846–54.

The effect of various percentages of lime, magnesium oxide, alumina and silica on viscosity were studied in a newly developed viscosimeter of the torsion type; simultaneously the various slags were studied under the Leitz heating microscope. The results are presented in tables and graphs.

Future Sources of Fuel and Power D. Hicks. *Iron and Coal Tr. Rev.* 1958, **177** (July 11) 77–81.

It is thought that the various estimates of the future growth of demand for all types of fuel have been excessive and, on the other hand, that too much emphasis has been laid on replacing coal by oil since oil reserves are likely to be exhausted much earlier than coal reserves. It is stressed that, in the interest of national economy, the use of oil for heating, gas generation, and steam raising should be reduced and replaced by the surplus of small coal and that much more should be done in utilizing coal for chemical purposes, especially the production of oil.

Gas-cooled Graphite-moderated 100 Mw Reactor Proposal for the German Reactor Programme. W. Junkermann and H. Benzler. *Atom u. Strom* 1958, **4** (July) 53–9 (In German).

The authors discuss the advantages of the British reactor design and propose it as a basis for a German power reactor but incorporating several improvements. These include higher pressure of the coolant and a more streamlined fuel element channel; the use of hollow elements should be left for later, but the graphite lattice should be so designed that 50 per cent or more of such metallic or ceramic elements could be introduced. If all the improvements were applied, the initial output of 100 Mw could be increased to 180 Mw. With the most unfavourable estimate of fuel element costs and without any return for recovered plutonium, the total cost would amount to 6.4 pf. per kwhr; with a government subsidy of two-thirds of the capital, this would be reduced to 4 pf. per kwhr; when using hollow elements and the same government subsidy, the cost would decrease to 2.5 pf. kwhr; and for a 500 Mw plant without subsidy, the cost would be 3.5 pf. per kwhr. This last mentioned cost would already be competitive with electricity generated in bituminous coal-fired power stations.

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The Standardization of Methods of Analsis of Coal and Coke. J. G. King. *Fuel* 1958, **37** (Oct.) 407–8.

In discussing the new BS 1016, Parts 6 and 7, 1958, it is pointed out that a guard tube containing manganese dioxide has been added to the Liebig method for carbon determination, to prevent escape of oxides of nitrogen. The "high temperature" alternative method has also been included.

The Determination of Carbon and Hydrogen by the Liebig Method; Elimination of the Errors Due to the Formation of Nitrogen Dioxide. M. P. Mendoza. *Fuel.* 1958, **37** (Oct.) 409–14.

Carbon values obtained with and without use of the manganese dioxide guard tube in the Liebig method are compared; the use of the tube gives better values. An empirical correction for hydrogen is submitted.

Evolution of Oxides of Nitrogen and of Sulphur during the Determination of Carbon and Hydrogen in Coal. A. H. Edwards. *Fuel* 1958, **37** (Oct.) 415–20.

The oxides of sulphur produced during combustion of coal are completely absorbed in a properly packed Liebig tube and the oxides of nitrogen removal by manganese dioxide. Only traces of oxides of nitrogen are evolved in the high temperature method.

Contribution to the Determination of Phosphorus in Solid Fuels. W. Radmacher and W. Schmitz. *Brennst-Chemie* 1958, **39** (Sept.) 274–9 (In German).

Four different methods for the determination of phosphorus are compared: 1. Combustion of sample in oxidizing atmosphere at 757 C ± 25 C with addition of phosphorus-binding salts; 2. Combustion of sample mixed with sodium carbonate and magnesium oxide in oxidizing atmosphere at 775 C ± 25 C; 3. Decomposition of sample with concentrated sulfuric acid and concentrated nitric acid; 4. Decomposition of sample with concentrated sulfuric acid in presence of selenium. None of these methods results in low values due to evaporation of phosphorus during combustion. A new rapid method of determining the phosphorus content of coke is

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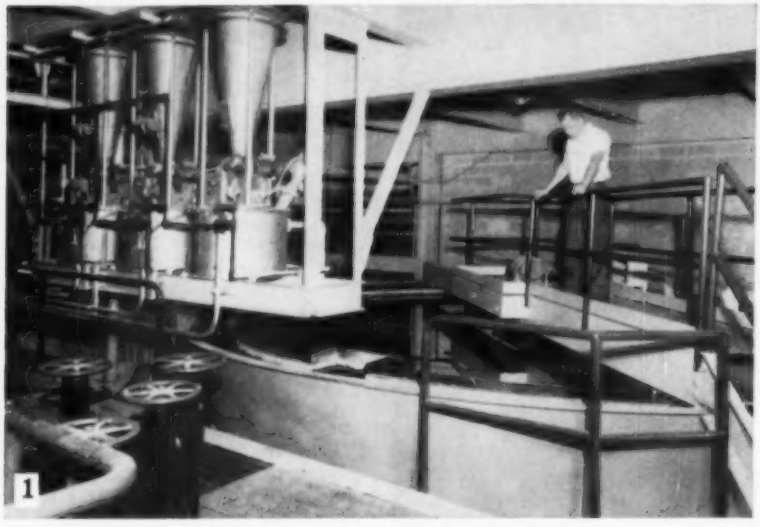

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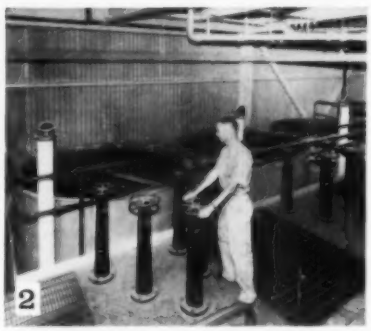

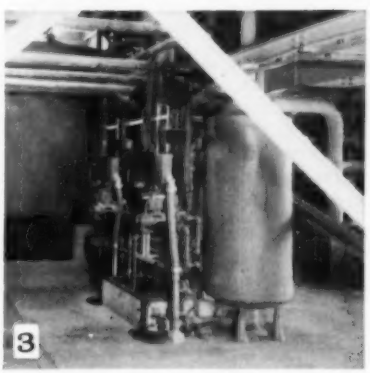

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described, which uses oxygen in the combustion process and reduces the time for the analysis to 10 min.

Studies in Bomb Calorimetry IX—Formation of Sulfuric Acid. R. A. Mott and C. Parker. *Fuel* 1958, **37** (Oct.) 371–81.

The studies on sulfur trioxide formation in the bomb during the combustion of coal and coke have shown that the sulpfur correction does not lead to gross inaccuracy. Working rules to prevent errors are presented and recommendations made for the application of corrections.

Experiences in the Non-Destructive Testing of Circular Welding Seams of Thick-Walled Tubes. A. Dombrowski and M. Wandelt. *B.W.K.* 1958, **10** (Oct.) 492–5 (In German).

Non-destructive testing of welds on site by X- and γ-rays and ultrasonics is discussed and the results of comparative tests reproduced and verified by polished sections. These show that none of these methods applied alone is able to give always reliable results and only a combination of all three gives a high probability of detecting all faults. The evaluation of the indications produced by the various methods, especially by ultra onics, requires many years of experience.

Improved Smoke-Measuring Devices. Anon. *Pwr. and Wks. Engng.* 1958, **53** (Aug.), 479.

By employing a cadmium photo cell, valve amplifiers have been eliminated in two new smoke indicating instruments. One of these is suitable for chimneys of up to 15 ft diam. and operates an alarm when a preset reduction of the intensity of a light beam occurs, and the other for chimneys of up to 40 ft diam. gives a continuous indication of the smoke density and can also actuate visual or audible alarms.

Grinding, Screening and Filtering

When You Crush and Pulverise Coal. U. B. Yeager. *Pwr. Engng.* 1958, **62** (July), 61–4, 114.

A review of machines available for crushing, grinding, and pulverizing solid fuels, including a Table indicating which of these machines is most suitable for the different fuels and purposes.

Ball Mill Grinding. Part II. The Application of Laboratory Scale Experiments in Industry. J. Nijman. *Brit. Chem. Engng.* 1958, **3** (Aug.), 414–7.

In scaling up from laboratory to full size plant, the following factors must be considered: Particle size

distribution after a single breakage event in a ball mill and the probability of breakage due to cascading and to cataracting of the balls. The distribution function appears not to be affected by scaling up, but simple rules for scale-up cannot be given.

Analysis and Testing, Research

Determination of the Inorganic Constituents in Australian Coals by Rapid Semi-micro (Photometric) Methods. C.S.I.T.O. Coal Research Section. *Chatswood*, N.S.W., T.C. 23, 1957 (July), 62 pp.

Pringle's methods worked out for the analysis of British coal ash have been found to be either not applicable to Australian coals or too tedious. A complete photometric scheme for the analysis of coal ash is now proposed and details of the procedure given. The scheme would also be applicable to boiler deposits and slag.

Spectrochemical Methods of Analysis as Applied to Mineral Matter Associated with Coal. K. Dixon. *Analyst* 1958, **83** (June), 362–71.

Spectrochemical solution methods are readily applicable to the analysis of the mineral matter in coal, coal ash, and a wide variety of associated minerals. Solutions are prepared by fusing the sample and then extracting the melt, or by wet oxidation. Calibration is carried out with synthetic standards prepared, whenever possible, from Specpure materials. Sodium and potassium are determined with a flame photometer. The techniques are appreciably faster than other published methods, and have a comparable precision.

From *C.E.G.B. Digest* 1958, **10** (Aug. 16), 2171.

Relationship between Sampling of Bituminous Coal and Accuracy of the Ash Content Determined. H. Paul. *Glückauf* 1958, **94** (July 5), 907–18 (In German).

Weight of sample as a function of particle size, sampling method and preparation, and determination of ash content are discussed, and the results obtained with a large number of samples and the standard deviations are tabulated. Laboratory, special, and routine analyses are compared. The accuracy obtainable in routine sampling and testing is discussed; the sampling error is generally greater than the preparation and analysis error, and ensuring the correct sampling procedure is thus specially important.

Sampling Dust and Fumes. Anon. *Mech. World* 1958, **138** (Aug.), 366.

The apparatus developed by B.I.S.R.A. for the isokinetic sampling

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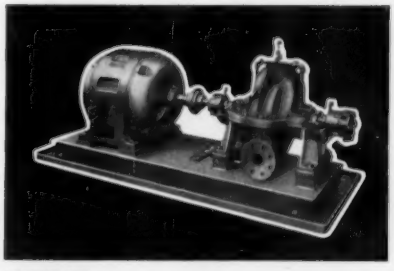

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up to 400,000 lbs./hr. for 150 psi boilers
up to 400,000 lbs./hr. for 250 psi boilers
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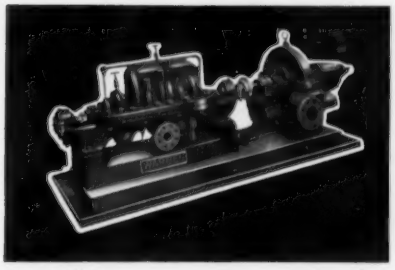

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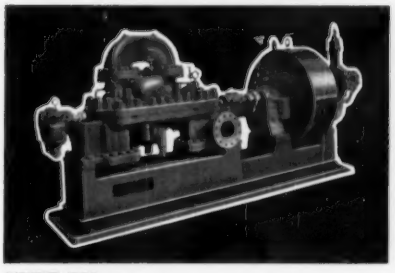

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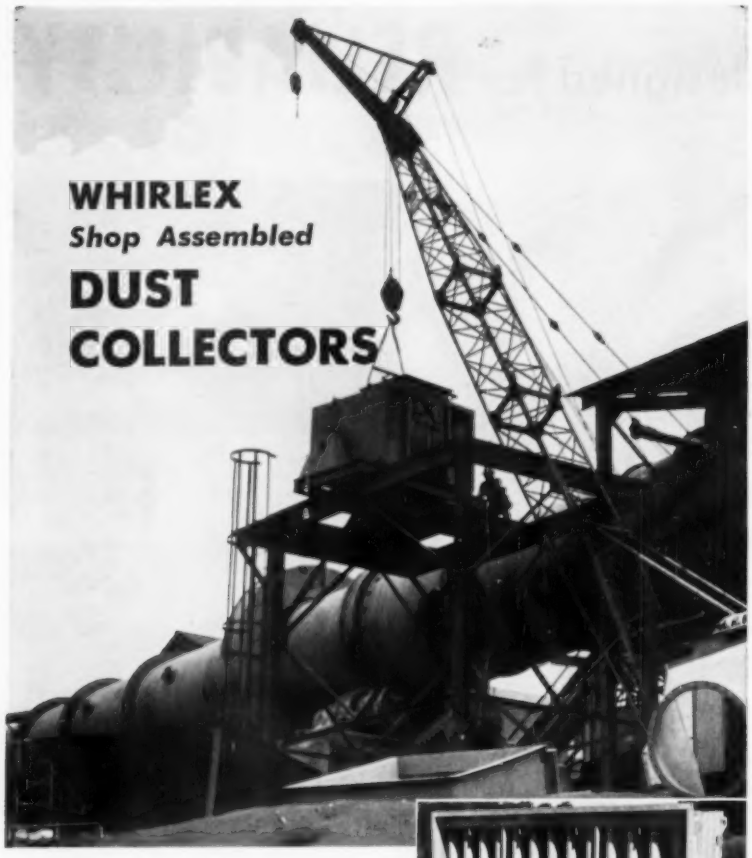

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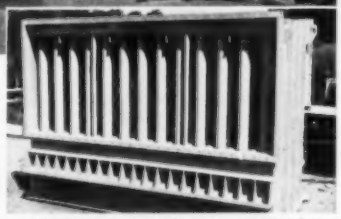

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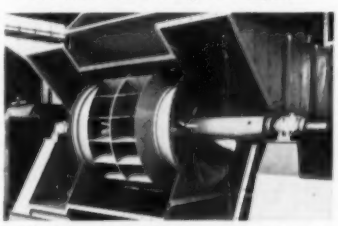

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of gas and the measuring of its dust content, e.g., waste gases containing red oxide fumes from steel-making processes, is now commercially available. The probe with a sharp-edged nozzle faces into the gases and the sample is withdrawn at the same velocity at which the gas flows through the duct. The gas is passed through a glass-fibre filter, cooled and metered. The correct sampling rate is obtained by pitot tube and temperature readings.

Steam Research—A Task of International Cooperation. E. Schmidt. *B.W.K.* 1958, **10** (Aug.), 369–70 (In German).

A report is presented of the first unofficial meeting of the International Committee held in London in July 1957, in which the work being carried out in Great Britain, Germany, U.S.A., and U.S.S.R. was discussed. Brief details are given of the research in progress in these countries and the difficulties encountered.

Nuclear Energy

Progress in Controlled Thermonuclear Research in the U.S.A. Anon. *Engineer* 1958, **206** (Oct. 10) 585–7.

The apparatus used and the results obtained so far at four American laboratories—Los Alamos Scientific Laboratory, Oak Ridge National Laboratory, Princeton University and University of California Radiation Laboratory—are outlined.

British Reactor of the Future. Anon. *Engineering* 1958, **186** (Sept. 12) 336–9.

Present investigations are concentrating on a reactor containing fuel operating at surface temperatures of 1000 C and heating a gaseous cooling medium to 750 C, which would drive a gas turbine connected to a compressor for circulating the gas (both installed inside the pressure vessel) and the exhaust at a temperature sufficient to generate steam at 500–600 C. The fuel would probably be a combination of fissile and fertile material (one atom U235 and 20 atoms Th232), the coolant gas helium or nitrogen, the moderator graphite or beryllium. Sketches of the arrangement of the reactor, the fuel elements and control rod drives are reproduced and the difficulties likely to be encountered, discussed. A 10 MW zero energy reactor will be built for study.

The Advanced Gas Cooled Reactor, A.G.R. Anon. *Engineer* 1958, **206** (Oct. 24) 656–8.

The most essential parts of a paper by R. V. Moore, H. Kronberger and L. Grainger presented at the Geneva

Conference are reproduced dealing with: 1. Fuel cycles for slightly-enriched reactors; 2. Use of UO_2 for long burn-up; 3. Development to higher temperature operation; 4. Other problems of the advanced gas cooled reactor; 5. The advanced gas cooled reactor (100 MW thermal, 28 MW electric, gas outlet temperature 500–575 C, fuel can surface temperature 600 C); 6. Conclusions.

The West German Nuclear Development. K. Writz. *B.W.K.* 1958, **10** (Sept.) 409–14 (In German).

The rapid development of research into nuclear problems can be gathered from the fact that 7 research reactors are operating or on order. A table gives the organization responsible for the order and that for which it is destined (mainly for Universities), foreign supplier and German contractor, type of reactor, fuel, moderator and reflector, output, neutron flux, cooling temperatures, control, shielding and experimental facilities. There is generally one reactor for a group of universities, technical and medical institutions. The power reactor program has not yet been finalized, but it is certain that they will be of different types, to be able to make comparison of their merits and economics.

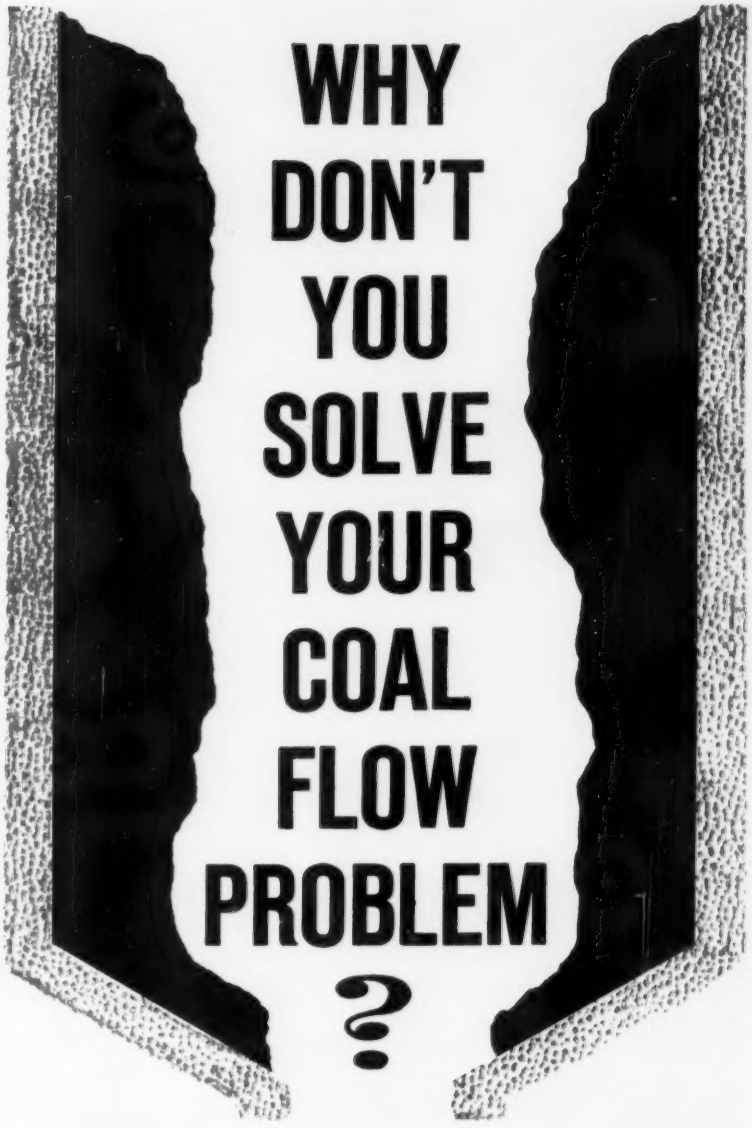
High Temperature Reactors. R. Schulten. *Atom & Strom* 1958, **4** (Oct). 79–82 (In German).

Some details are given of the high temperature reactor project worked out by BBC-Krupp. The reactor has a thermal output of 48 MW and an electrical output of 15 MW, and can be operated in the temperature range 500–1000 C and a pressure of 7–10 at. The fuel is 2 per cent enriched uranium carbide, the moderator graphite, the coolant a mixture of neon and helium. Thorium is used as breeder material. The fuel and moderator are both in spherical form. To reduce the shielding problem, the reactor is to be surrounded by a double steel wall with the space between the two shells kept at a higher pressure than that inside the reactor, so that no leakage of poisonous products to the outside is possible.

Grinding, Screening and Filtering

Mixing of Solids. J. B. Gayle, O. L. Lacey and J. H. Gary. *Ind. Engng. Chem.* 1958, **50,** Part I, (Sept.) 1279–82.

A method is described for following the mixing process which is applicable to ditributions consisting of any finite number of components distinguishable as discrete particles.



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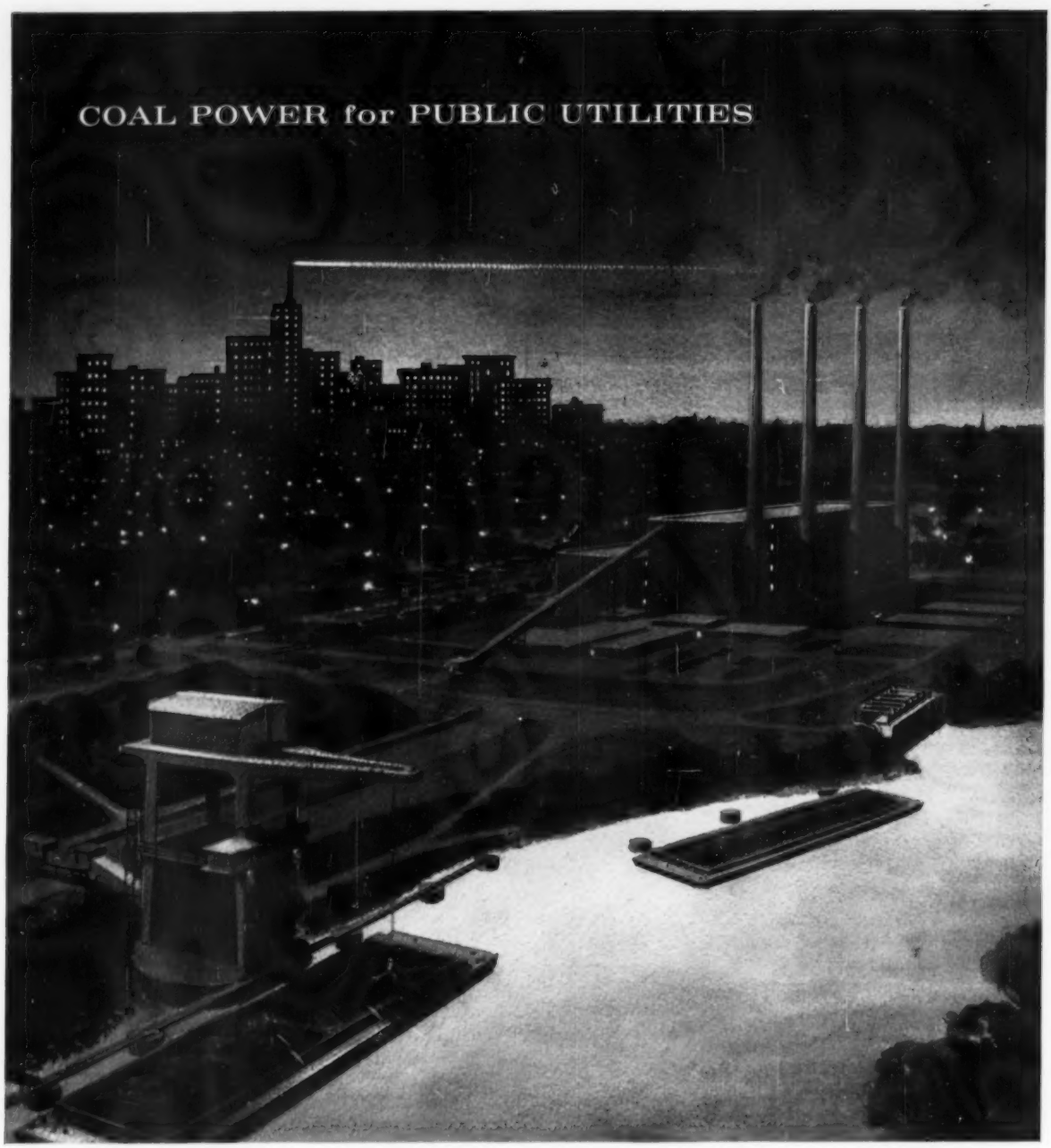

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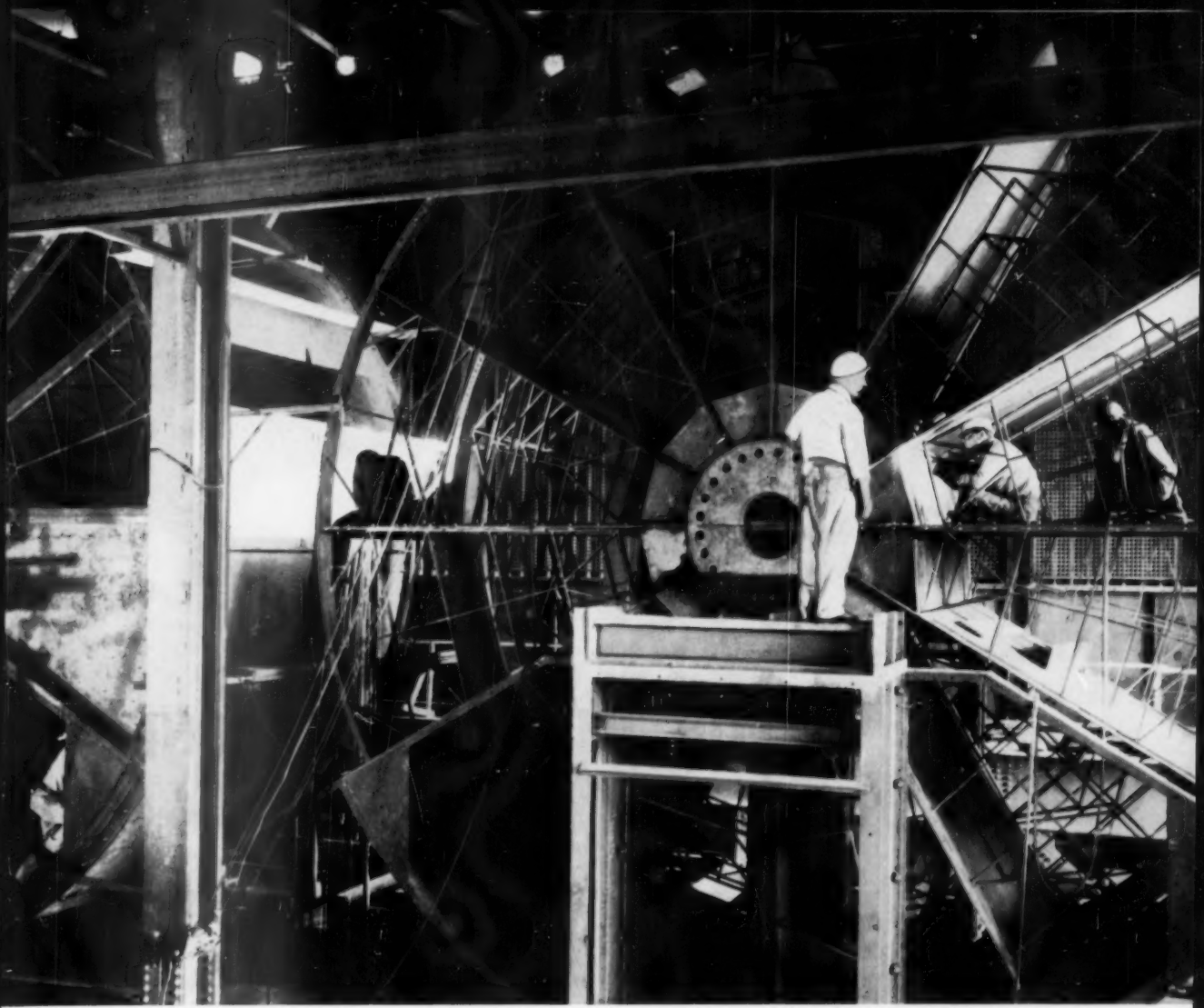

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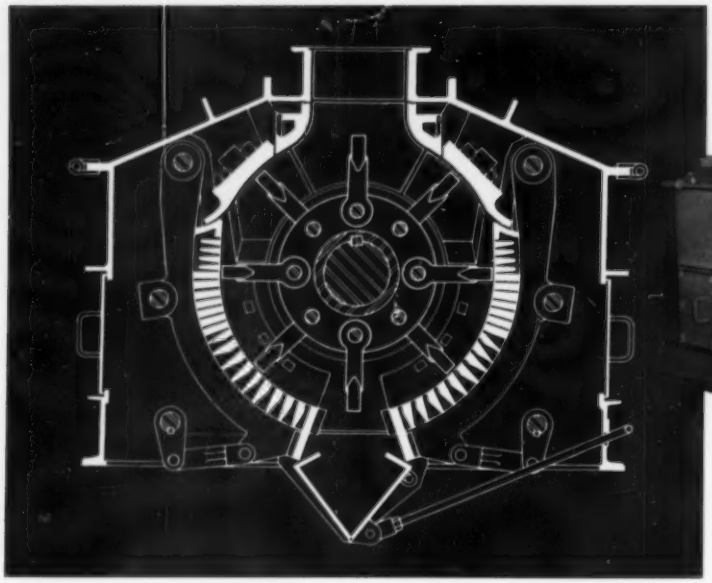

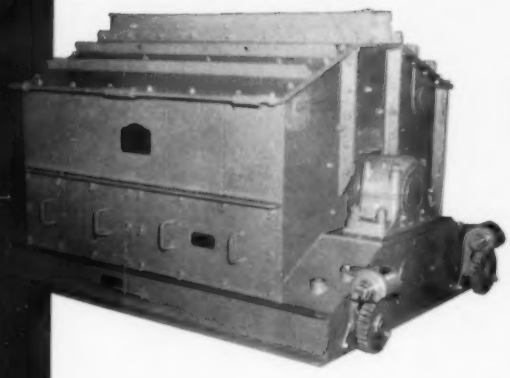

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Pennsylvania CRUSHERS

6 Ton Hot Reheat Header

Model test set-up of hot reheat line as reproduced above is approximately 1/10th actual size of the model. Circled area shows position of chrome-moly header in the line.

Size of this hot reheat header can be seen by comparison with men in the picture. It is 21″ O.D., fabricated of 2¼% chrome, 1% molybdenum steel.

PRETESTED and PREFABRICATED by Pittsburgh Piping

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The model shown above exactly duplicates—from an engineering standpoint—a hot reheat line which is part of a high-pressure, high-temperature piping system fabricated by Pittsburgh Piping.

The inset shows the position and relative size of the header in the line, and the main illustration is an actual photograph of this header as fabricated in our shops. The complete system, which includes chrome-moly and stainless steel piping fabrication, is one of scores of installations which we have model-tested, fabricated, and erected.

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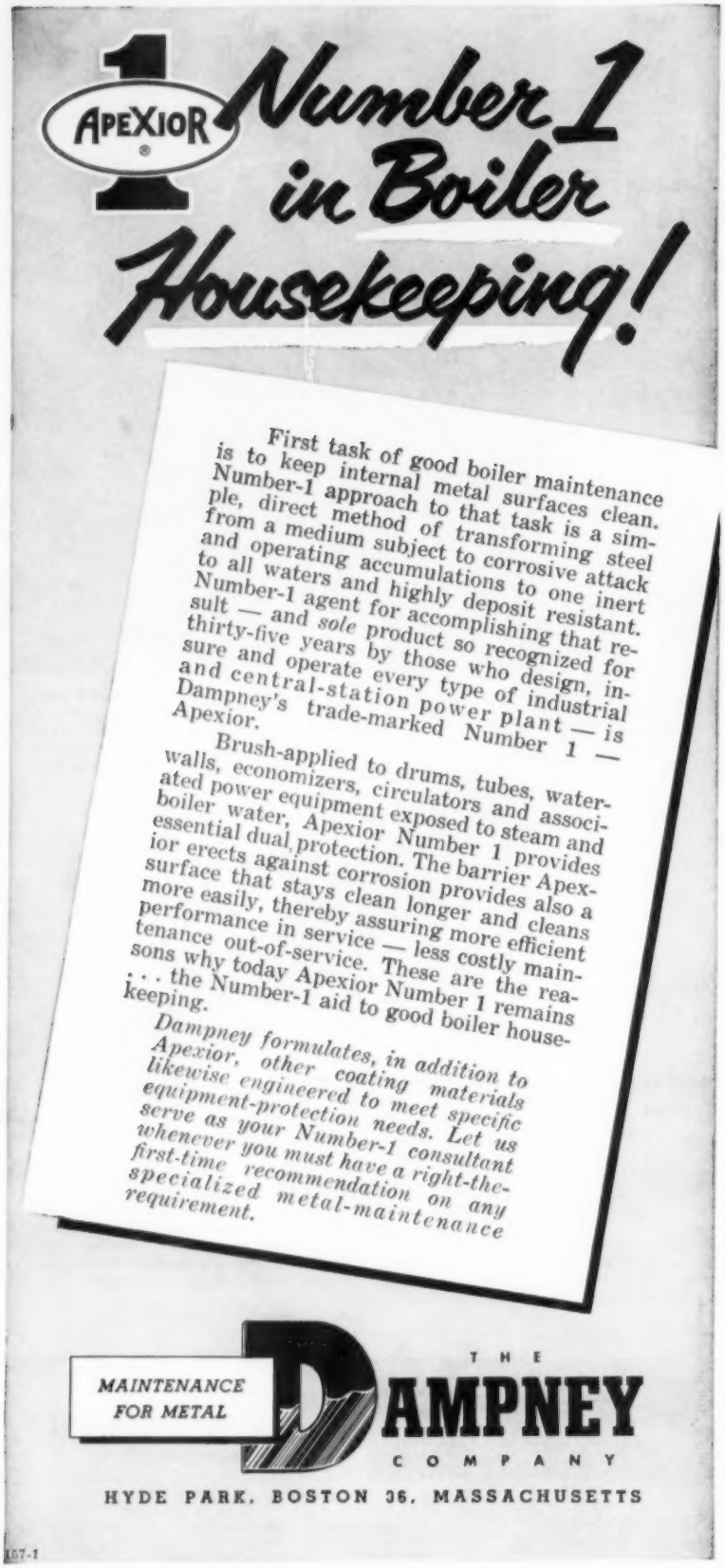
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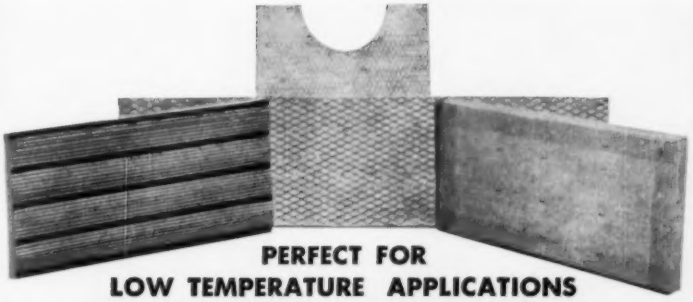

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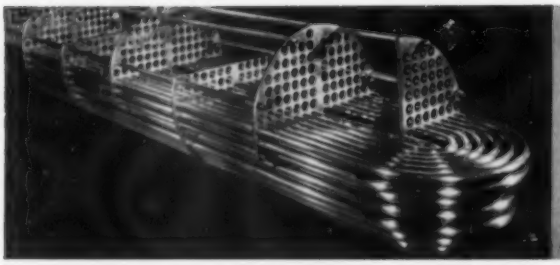

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Edited by David S. Hibbard, Metallurgical Engineer
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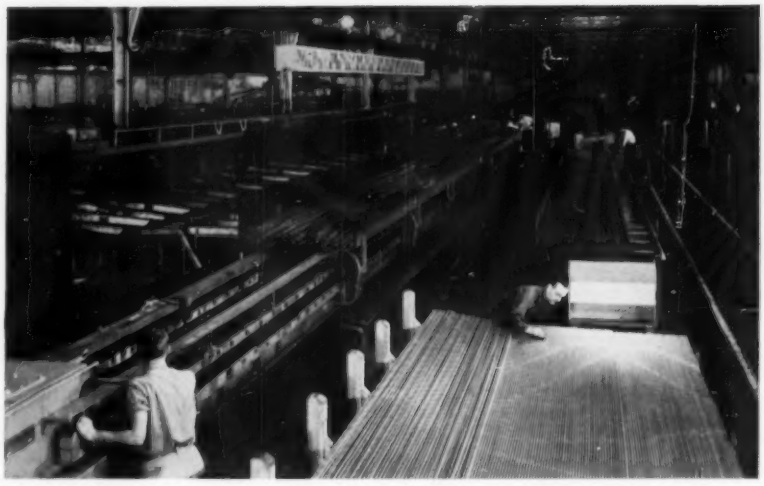

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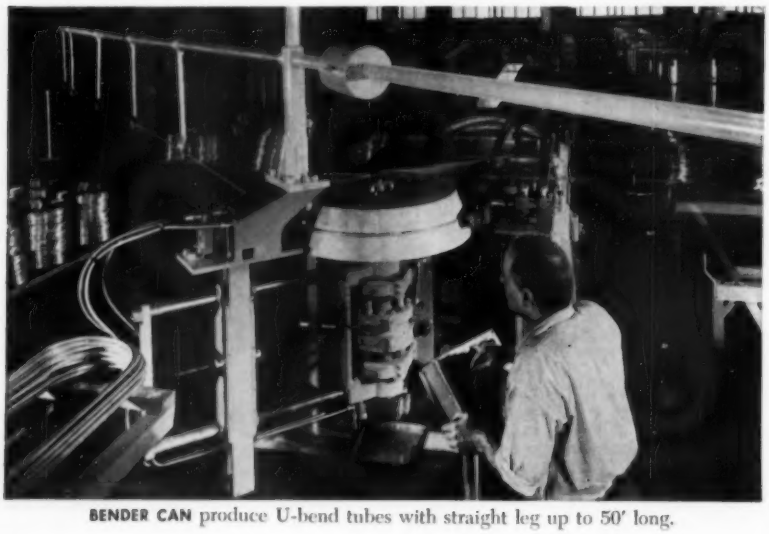

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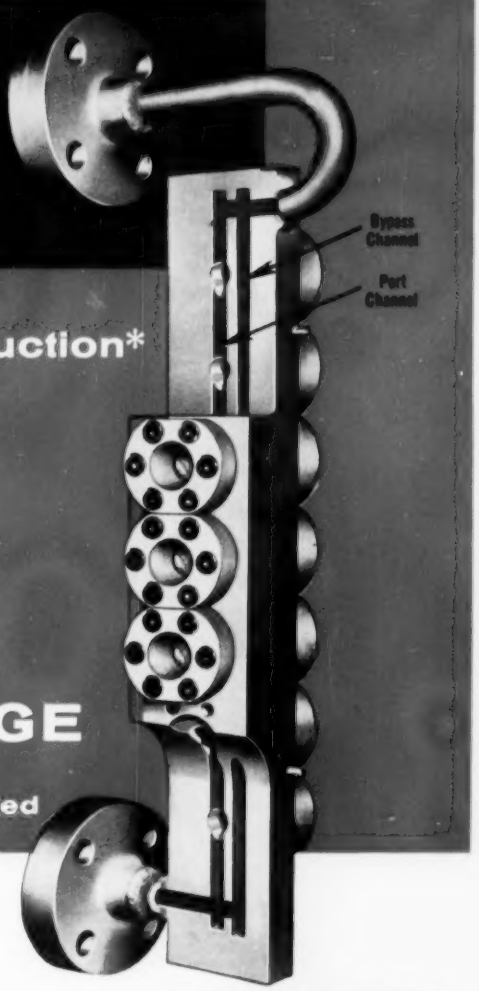

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Citric Acid -- Dowell's New Service for Cleaning Stainless Steel Process Equipment

Now, for the first time, plant operators can be sure of a new degree of safety in the cleaning of their pressure units containing austenitic stainless steel—for example, heat exchangers, stainless-clad pressure vessels, atomic reactors, and supercritical-pressure steam generators. Citric Acid service by Dowell provides a new, effective method for these special chemical cleaning situations.

The Citric Acid used in Dowell chemical cleaning is inhibited with an *exclusive chloride-free* inhibitor. Cleaning with this new field-proven solution assures a chloride-free solvent system, and thus helps prevent chloride stress-corrosion cracking.

Dowell Citric Acid also provides other significant advantages: Citric Acid stabilizes dissolved iron and helps prevent precipitation of insoluble iron compounds when neutralizing chemicals are used. Flushing of the unit is not as difficult when Citric Acid is used. Citric Acid is especially suitable where stainless steel and other metals are used together in construction of the unit.

Citric Acid cleaning with a chloride-free inhibitor is just one of the new ideas from Dowell research. Other recent contributions include the new "white glove" standards of cleanness, copper removal agents and the new jetting device for cleaning heat exchanger tube bundles.

Ask your Dowell representative about Citric Acid service and Dowell chemical cleaning programs for your plant equipment. Dowell, the leader in chemical cleaning service and research, operates in every major industrial area through 165 offices and stations. Dowell, Tulsa 1, Oklahoma.

Chemical cleaning service for all industry DOWELL

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